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Synopses of Federal Demonstrations of Innovative Site Remediation Technologies

DEPARTMENT OF ENERGY UNITED STATES OF AMERICA

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

DEPARTMENT OF THE AIR FORCE UNITED STATES OF AMERICA

DEPARTMENT OF DEFENSE UNITED STATES OF AMERICA

Federal
Remediation
Technologies
Roundtable

DEPARTMENT OF THE ARMY UNITED STATES OF AMERICA

US Army Corps
of Engineers

DEPARTMENT OF THE NAVY UNITED STATES OF AMERICA

U.S. DEPARTMENT OF THE INTERIOR BUREAU OF RECLAMATION

Prepared by the

Member Agencies of the
Federal Remediation Technologies Roundtable

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EPA/540/8-91/009
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U.S. Environmental Protection Agency
Department of Defense
    U.S. Army
    U.S. Army Corps of Engineers
    U.S. Navy
    U.S. Air Force
Department of Energy
Department of Interior
    Bureau of Reclamation

Summer 1991

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NOTICE

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PREFACE

This collection of abstracts, compiled by the Federal Remediation Technology Roundtable, describes field demonstrations of innovative technologies to treat hazardous waste. The collection is intended to be an information resource for hazardous waste site project managers for assessing the availability and viability of innovative technologies for treating contaminated ground water, soils, and sludge. It is also intended to assist government agencies coordinate ongoing hazardous waste remediation technology research initiatives, particularly those sponsored by the U.S. Environmental Protection Agency (EPA), the U.S. Department of Defense (DoD), and the U.S. Department of Energy (DOE). Innovative technologies, for the purposes of this compendium, are defined as those technologies for which detailed performance and cost data are not readily available.

The demonstrations contained herein have all been sponsored by EPA, DoD, and DOE. In total, 75 demonstrations in seven different technology categories are described. A matrix listing these demonstrations, the type of contaminant, media that can be treated, and the treatment setting for each innovative technology is provided in Exhibit 1 on page vii.

This document represents a starting point in the review of technologies available for application to hazardous waste sites. This compendium should not be looked upon as a sole source for this information -- it does not represent all innovative technologies nor all technology demonstrations performed by these agencies. Only Federally-sponsored studies and demonstrations that have tested innovative remedial technologies with site specific wastes under realistic conditions as a part of a full-scale field demonstration are included. Those studies included represent all that were provided to the Federal Remediation Technology Roundtable at the time of publication. Information collection efforts are ongoing.

The enclosed abstracts were obtained from the following resources:

- U.S. Department of Energy and U.S. Air Force, *Joint Technology Review Meeting on Soil and Ground Water Remedial Technologies*, The Hazardous Waste Remedial Actions Program, Air Force Engineering Services Center, Office of Technology Development, Atlanta, Georgia, February 6-8, 1990.

- U.S. Department of Defense, *Installation Restoration and Hazardous Waste Control Technologies*, prepared for the U.S. Army Toxic and Hazardous Materials Agency by ITT Research Institute, The National Institute for Petroleum Energy Research, Bartlesville, Oklahoma, August 1990, (Report No. CETHA-TS-CR-90067).

- The Alternative Treatment Technology Information Center (ATTIC), sponsored by the U.S. Environmental Protection Agency, Office of Environmental Engineering and Technology Demonstration.

- U.S. Environmental Protection Agency, *The Superfund Innovative Technology Evaluation (SITE) Program: Technology Profiles*, Office of Solid Waste and Emergency Response and Office of Research and Development, Washington, DC, November 1990, (EPA/540/5-90/006).

The Federal Remediation Roundtable

This publication was prepared under the auspices of the Federal Remediation Technologies Roundtable (Roundtable). This organization was created to establish a process for applied hazardous waste site remediation technology information exchange, to consider cooperative efforts of mutual interest, and to develop strategies and analyze remedial problems that will benefit from the application of innovative technologies. The Roundtable is comprised of representatives from several Federal agencies:

Environmental Protection Agency, Technology Innovation Office (EPA/TIO)

The mission of the Technology Innovation Office (TIO) is to increase applications of innovative treatment technology by government and industry to contaminated waste sites, soils, and ground water. TIO intends to increase usage of innovative techniques by removing regulatory and institutional impediments and providing richer technology and market information to targeted audiences of Federal agencies, States, consulting engineering firms, responsible parties, technology developers, and the investment community. The scope of the mission extends to Superfund sites, corrective action sites under the Resource Conservation and Recovery Act (RCRA), and underground storage tank clean-ups. By contrast, TIO is not a focus for EPA interest in treatment technologies for industrial or municipal waste streams, for recycling, or for waste minimization.

Environmental Protection Agency, Office of Research and Development (EPA/ORD)

The Office of Research and Development (ORD) Superfund Innovative Technology Evaluation (SITE) program supports development of technologies for assessing and treating waste from Superfund sites. The SITE program was authorized by the Superfund Amendments and Reauthorization Act of 1986 with the goal of identifying technologies, other than land disposal, that are suitable for treating Superfund wastes. The program provides an opportunity for technology developers to demonstrate their technology's capability to successfully process and remediate Superfund waste. EPA evaluates the technology and provides an assessment of potential for future use for Superfund cleanup actions. The SITE program has currently evaluated or supported research efforts for more than 100 innovative treatment technologies. The SITE program is administered by EPA's Risk Reduction Engineering Laboratory (RREL) in Cincinnati, Ohio.

Department of Defense (DoD), Defense Environmental Restoration Program (DERP)

The Office of the Secretary of Defense (OSD), operating through the Deputy Assistant Secretary of Defense, Environment (DASD (E)), establishes policy and monitors the Armed Force's execution of the DoD hazardous waste site cleanup program. The Defense Environmental Restoration Program (DERP) funds activities at over 17,000 DoD sites located on nearly 1,700 properties through the Installation Restoration Program (IRP). The DoD works cooperatively with the Environmental Protection Agency and the States toward the goal of taking timely, effective, and efficient actions at all stages of the DERP. Research and development of better methods for site investigation and cleanup is an important part of DERP. Many innovative technologies have been developed and demonstrated to improve the speed and cost-effectiveness of DoD site cleanups.

U.S. Army Corps of Engineers

In support of the Army's Installation Restoration (IR) Program, the U.S. Army Corps of Engineers has the responsibility of ensuring the development of necessary and improved technology for conduct of the Program. The U.S. Army Corps of Engineers is also charged with the responsibility for developing improved pollution abatement and environmental control technology in support of the U.S. Army Material Command industrial complex (Pollution Abatement or PAECT Program). The purpose of the IR Decontamination Development Program is to provide R&D support to required assessment and cleanup actions at Army installations. Efforts include evaluating commercially available state-of-the-art technologies as well as developing new, innovative technologies that are more economical and efficient than existing technology. The PAECT program addresses waste minimization and disposal alternatives for the Army's industrial operations.

U.S. Army Toxic and Hazardous Materials Agency (USATHAMA)

The U.S. Army Toxic and Hazardous Materials Agency (USATHAMA), a Field Operating Activity (FOA) of the U.S. Army Corps of Engineers, is a major focal point in the program management and support efforts of the Army-wide environmental program. With its principal focus directed toward supporting the installation in achieving and maintaining environmental compliance, the Agency's activities fall into five major categories:

-- Environmental Compliance;
-- Installation Restoration Program (IRP);
-- Environmental Training and Awareness;
-- Research and Development (R & D); and
-- Environmental Information Management.

U.S. Air Force, Engineering and Services Center (AFESC)

The Air Force Engineering and Services Center (AFESC) is responsible for identifying, developing, and testing technologies that may be useful for remediating contaminated sites as part of the Air Force's Installation Remediation Program.

U.S. Navy, Naval Energy and Environment Support Office (NEESA)

The Naval Energy and Environmental Support office (NEESA), in Port Hueneme, California, provides technology transfer information to Navy and Marine Corps Installations with hazardous waste cleanup responsibilities. NEESA wrote and periodically updates the Navy's *Remedial Action Technology Guide*, which provides guidance to Navy commands on preview technologies including cost data. NEESA is also involved in developing Remedial Action Contracts, which will be available Navy-wide to implement cleanups. NEESA coordinates closely with the Navy Civil Engineering Laboratory, in Port Hueneme, California, to match new R&D efforts to actual field sites in order to test new technologies. The technology transfer mission extends to CERCLA actions, RCRA corrective actions and UST cleanups/removals.

Department of Energy, Office of Technology Demonstration (DOE/OTD)

The Department of Energy's (DOE) Office of Technology Demonstration (OTD) was established to identify technologies in the research and development and demonstration (RD&D) stage, and to demonstrate, test, and evaluate those technologies that will provide DOE with accelerated and/or improved methods for achieving its environmental goals as specified in its Five-Year Plan.

Future Demonstrations

This publication will be updated on a periodic basis. If you will be conducting a demonstration featuring an innovative hazardous waste treatment technology in the future, or if you are aware of any project that is relevant to this collection, but has been omitted, please forward this information to TIO:

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For your convenience, we have included, at the end of this volume, the Innovative Remedial Technologies Information Collection Form to guide you in formatting the information for inclusion in this compendium. The Roundtable developed this form as a model for use in collecting findings on innovative technologies and their applications, effectiveness, and costs.

The form is intended to facilitate new data collection efforts and to indicate the data we are most interested in capturing. If, however, you have already collected and recorded the information in an alternative format, please feel free to forward any previously written abstract or summary. We will reformat it to be included in this compendium.

If you have any comments on the usefulness and clarity of this publication, please complete the suggestion form on the last page, and send it to Daniel Powell at the address listed above.

Exhibit 1

Matrix Showing the Various Technology/Contaminant/Media Combinations Addressed within this Compendium

Innovative Technology	Contaminant								Media				Treatment Setting		Page
	Halogenated volatiles and semivolatiles	Nonhalogenated volatiles and semivolatiles	PCBs	Pesticides	Cyanides	Metals	Radioactive Materials	Explosives	Surface Water	Ground Water	Soils	Sludges	In Situ	Ex Situ	
Bioremediation	✓	✓	✓					✓		✓	✓	✓	✓	✓	1
Chemical Treatment	✓	✓		✓	✓	✓	✓			✓	✓	✓		✓	29
Thermal Treatment	✓	✓	✓	✓		✓						✓		✓	33
Vapor Extraction	✓	✓								✓	✓		✓		51
Soil Washing	✓	✓	✓	✓		✓					✓	✓		✓	65
Solidification/Stabilization	✓	✓	✓	✓	✓	✓				✓	✓	✓	✓	✓	77
Other Physical Treatment	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	89

Bioremediation

DEPARTMENT OF THE AIR FORCE
MCMXLVII
UNITED STATES OF AMERICA

Above-Ground Biological Treatment of Trichloroethylene

Trichloroethylene (TCE) in Ground Water

Technology Description

In this treatment, methane-degrading bacteria co-metabolize short-chain, chlorinated aliphatic hydrocarbons. This technology is applicable to the removal of short chain (C_1 and C_2) chlorinated aliphatic hydrocarbons from water. It can be used as an above-ground "pump and treat" method of treating contaminated ground water. Other applications can include in situ decontamination or the removal of similar compounds from any water stream.

An enzyme, a non-specific oxygenase that metabolizes methane, attacks trichloroethylene (TCE). The bacteria cannot, however, use TCE as "food" but must have methane as a carbon source. The reaction can take place in a bioreactor or in situ. A mixture of oxygen and methane is passed through the reactor or reaction zone to sustain the microbial population. The contaminated water is allowed to percolate down through the bed. The packing material can be soil, but care must be taken to avoid plugging.

Technology Performance

A field pilot testing of this treatment was conducted at Tinker Air Force Base, Oklahoma, during 1989. Approximately 80 percent destruction of TCE was achieved. Complete biodegradation may be achieved with lengthening of the reactor columns. Flow rate for the contaminated water in this process is two to three L/min, with a retention time of 20 to 50 minutes in the reactor, depending upon the packing material used. No hazardous intermediate compounds are created with this process.

Remediation Costs

Cost information is not available.

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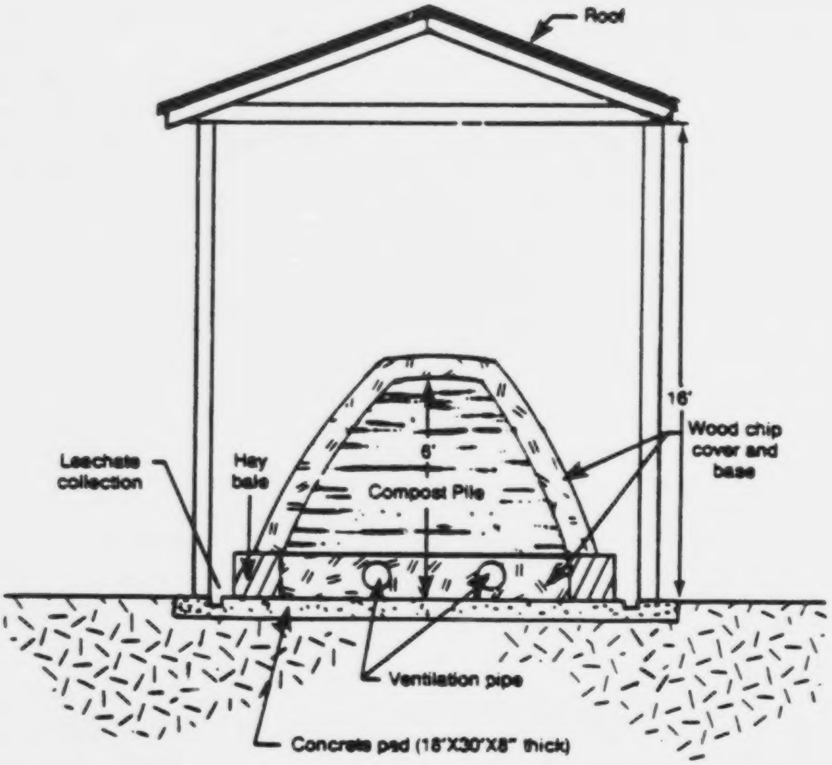
Roof
16'
Wood chip cover and base
Leachate collection
Hay bale
6'
Compost Pile
Ventilation pipe
Concrete pad (18'X30'X8" thick)

DEPARTMENT OF THE ARMY UNITED STATES OF AMERICA 1775

Aerated Static Pile Composting

Explosives (TNT, RDX, HMX) in Lagoon Sediments

Technology Description

Composting is a process by which organic materials are biodegraded by microorganisms, resulting in the production of organic and inorganic byproducts and energy in the form of heat. This heat is trapped within the compost matrix, leading to the self-heating phenomenon known as composting. Composting is initiated by mixing biodegradable organic matter (explosives in this study), with organic carbon sources and bulking agents, which are added to enhance the porosity of the mixture to be composted.

In "static pile" composting, an aeration/heat removal system is utilized to increase process control over the composting system. The aeration/heat removal system typically takes the form of a network of perforated pipe underlying the compost pile. The pipe is attached to a mechanical blower and air is periodically drawn or forced through the compost to effect aeration and heat removal.

The composting test facilities were constructed of concrete test pads with runoff collection systems and sumps, covered by a roof to protect the compost piles from weather and to minimize the amount of moisture collected in the sump. Bulking agents and carbon sources consisted of horse manure, alfalfa, straw, fertilizer and horse feed. Baled straw was used to contain the pile contents, and was arranged in a ring around the perimeter of each pile. Sawdust and hardwood mulch were used to construct the pile bases, provide additional bulking material, and insulate the piles. After mixing, the compost was transported to the composting pads. Each compost pile contained a system of pipes connected to a blower, as described above. A cross-sectional schematic diagram of a compost pile is provided.

Technology Performance

The primary objective of this study was to evaluate the utility of aerated static pile composting as a technology for remediating soils and sediments contaminated with the explosives TNT, HMX, RDX, and tetryl.

Secondary objectives included evaluating the efficacy of thermophilic (55°C) versus mesophilic (35°C) composting, evaluating different materials handling and process control strategies, and determining transformation products when Standard Analytical Reference Materials (SARMs) were available.

Temperature was the primary test variable investigated. The temperature of one set of compost piles was kept within the mesophilic range; the temperature of the second set of piles was kept in the thermophilic range. The initial concentration of explosives in test sediments collected from the lagoon was 17,000 mg/kg. Phase I (piles 1 and 2) was conducted with a mixture of lagoon sediments, sawdust, wood chips, and a straw/manure mixture. Based on data received from phase I, phase II (piles 3 and 4) added alfalfa and horse feed to the compost mixture to increase the concentration of biodegradable organic carbon in the compost mixture. After 153 days of composting, the solvent-extractable total explosives were reduced to 376 mg/kg and 74 mg/kg in the mesophilic and thermophilic piles, respectively. The mean percent reductions of extractable TNT, RDX and HMX were 99.6, 94.8, and 86.9 weight percent in the mesophilic piles, and 99.9, 99.1, and 95.6 weight percent in the thermophilic piles.

The results of this field demonstration indicate that composting is a feasible technology for decontaminating explosives-contaminated soils and sediments. Further investigation is warranted for optimizing the materials balance and soil loading rate for mixtures to be composted, minimizing bulking agent used, and developing a design and operation management plan for a full-scale composting facility. In addition, the compost residue should be subjected to a toxicity evaluation and more extensively analyzed to determine the final fates of HMX, RDX, TNT, and tetryl.

Remediation Costs

Cost information is not available.

General Site Information

This field-scale demonstration project was conducted at the Louisiana Army Ammunitions Plant (LAAP). Compost piles were constructed and tested at LAAP between December 1987 and April 1988. Phase I piles were tested for 33 days; phase II piles were tested for 153 days. Approximately 21 cubic yards of sediment was excavated from Pink Water Lagoon No. 4 for use in this study.

LAAP was built to load and pack ordinance for the U.S. Army. Explosives have never been manufactured at the facility, but are brought in and utilized in loading, assembling, and packing lines. Initially, the area where the field demonstration was conducted was used as a burning grounds to dispose of out-of-specification ordnance. These burning pits were converted to lagoons in the mid-1940s. The lagoons were used to dispose of wastewater generated during wash down of the munitions loading lines. Equipment used to load munitions was washed with water, and the resulting wastewater contained high concentrations of suspended explosives ("pink water"). Pink water was transported to the unlined lagoons and dumped into individual lagoons via a concrete spillway. Suspended explosives settled to the bottom of the lagoons. Over the period of approximately 30 years during which pink water was disposed of in the lagoons, high concentrations of explosives accumulated in the upper sediment. The highest concentrations (300,000-600,000 mg/kg) accumulated near the spillways. In October 1984, the pink water lagoon site at LAPP was proposed for inclusion on the National Priority List (NPL).

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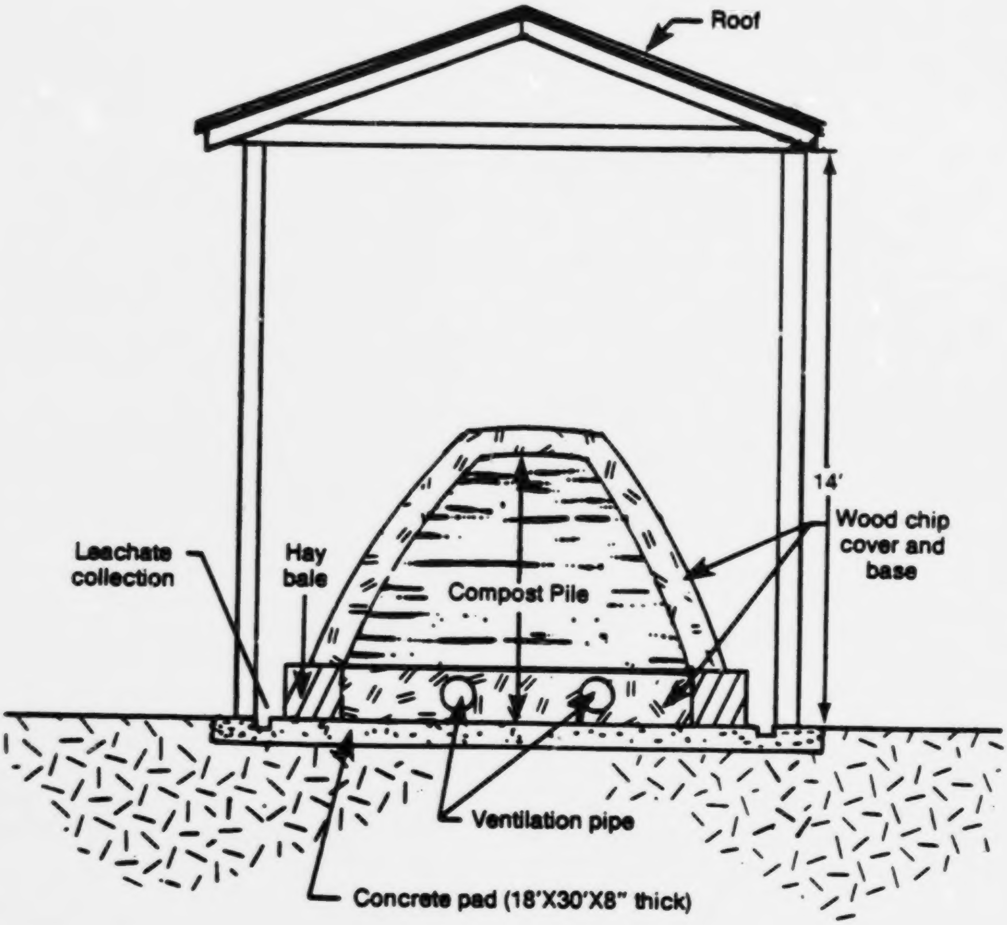
Roof
14'
Wood chip cover and base
Leachate collection
Hay bale
Compost Pile
Ventilation pipe
Concrete pad (18'X30'X8" thick)

Aerated Static Pile Composting

Propellants (Nitrocellulose) in Soil and Sediments

Technology Description

Composting is a process by which organic materials are biodegraded by microorganisms, resulting in the production of organic and inorganic byproducts and energy in the form of heat. This heat is trapped within the compost matrix, leading to the self-heating phenomenon known as composting. Composting is initiated by mixing biodegradable organic matter (nitrocellulose (NC) in this study), with organic carbon sources and bulking agents, which are added to enhance the porosity of the mixture to be composted.

In "static pile" composting, an aeration/heat removal system is utilized to increase process control over the composting system. The aeration/heat removal system typically takes the form of a network of perforated pipe underlying the compost pile. The pipe is attached to a mechanical blower and air is periodically drawn or forced through the compost to effect aeration and heat removal. The primary objective of hazardous materials composting is to convert hazardous substances into innocuous products for ultimate disposal, such as land application.

The composting test facilities were constructed of concrete test pads with runoff collection systems and sumps, covered by a roof to protect the compost piles from weather and to minimize the amount of moisture collected in the sump. Bulking agents and carbon sources consisted of a cow manure slurry, alfalfa, straw, and horse feed. Baled straw was used to contain the pile contents, and was arranged in a ring around the perimeter of each pile. Sawdust and hardwood mulch were used to construct the pile bases, provide additional bulking material, and insulate the piles. After mixing, the compost was transported to the composting pads. Each compost pile contained a system of perforated and non-perforated pipes connected to a blower. The blowers were used to pull air through the compost piles to promote aeration and remove excess heat. A cross-sectional schematic diagram of a compost pile is provided.

Technology Performance

The primary objective of this study was to evaluate the utility of aerated static pile composting as a technology for NC fine (out-of specification NC) remediation and destruction of soils contaminated with NC. Secondary objectives included evaluating the efficacy of thermophilic (55°C) versus mesophilic (35°C) composting, determining a maximum soil loading rate, and comparing different process control and material handling strategies.

The test variable in compost piles 1 and 2 (phase I) was temperature. The temperature of pile 1 was kept within the mesophilic range, and the temperature of pile 2 was kept in the thermophilic range. The concentration of NC in test soils collected from the dredge basin were 18,800 mg/kg for phase I tests. After mixing, total NC concentrations in pile 1 were 3,670 mg/kg, and concentrations in pile 2 were 3,608 mg/kg. After 152 days of the study, mean total NC concentrations were 651 mg/kg and 54 mg/kg, respectively. Information concerning the effect of temperature on the NC concentration was inconclusive, however, because there were apparent discrepancies in the starting data gathered for pile 1.

The test variable in piles 3 and 4 (phase II) was the degree of soil loading within each pile. The initial soil loading was increased from 19 percent in phase I to 22 percent in pile 3, and 32.5 percent in pile 4. The concentration of NC in tests soils collected for phase II was 17,027 mg/kg. After mixing, the concentrations of NC in pile 3 were 7,907 mg/kg, and 13,086 mg/kg in pile 4. After 112 days of the study, total mean concentrations of NC were 30 mg/kg and 16 mg/kg, respectively. Both piles showed greater than 99.5 percent reduction of NC from the starting point of the test. These results suggest that successful composting will likely occur at sediment loading rates of up to 50 percent or exceeding 50 weight percent.

The results of this field demonstration indicate that composting is a feasible technology for reducing the extractable NC concentration in contaminated soils. In addition, this study provides tentative evidence indicating that NC can be degraded when incorporated into a mixture to be composted at a high concentration. The fate of the NC could not be determined; however, microbial degradation of the likely process.

Remediation Costs

Cost information is not available.

General Site Information

This field-scale demonstration project was conducted at the Badger Army Ammunitions Plant (BAAP) in Sauk County, Wisconsin. Four compost piles were constructed at BAAP during the period from April 1988 to January 1989. The first set of compost piles was tested for 151 days; the second set was tested for 112 days. Approximately 13 cubic yards of test soils were excavated from Dredge Spoil Basin No. 1 for use in this study.

Constructed in 1942, the plant operated intermittently over a 33-year period, producing single- and double-base propellants for rocket, cannon, and small arms ammunition. During the plant's period of active operation, various chemical materials were produced, and the associated wastes and manufacturing byproducts were disposed on-site. The wastes included acids, nitroglycerin, and nitrocellulose (NC). As a result of the disposal practices, contamination of soils, the underlying aquifer, and, to some extent, surface waters have occurred.

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DEPARTMENT OF THE NAVY • UNITED STATES OF AMERICA

Biodecontamination of Fuel Oil Spills

Fuel Oil in Soil

Technology Description

In this treatment, biodegradation is accomplished by applying special oil-degrading bacteria to a bioreactor while filling the reactor with leachate water. As the reactor overflows, bacteria are carried to a spray field sump and then to injection wells and the spray field. Surface sprayers apply the treated leachate water on the spray field while the injection wells apply the treated leachate water to soil under the buildings. As more water is added to the system and the ground under the buildings, the contaminated area becomes saturated. Run-off water along with leachate water is collected in a trench down-slope from the contaminated area. The collected water is pumped back to the aerated reactor where bacterial growth on the high surface area matrix, on which some of the bacteria are immobilized, occurs. Clean nutrient-, detergent-, and oxygen-enriched water with bacteria is recirculated to the spray field and injection wells.

Technology Performance

The microorganisms function best at temperatures between 20° and 35° C.

Remediation Costs

The site was cleaned to a satisfactory level for approximately $37,000, not including shipping the equipment to the site, installation labor supplied by facility personnel, and analytical costs.

General Site Information

This method was implemented to clean up a fuel oil spill resulting from leaking pipes at a Naval Communication Station at Thurso, Scotland. The contaminated area had a considerable slope, and the contaminated soil was a thin layer over a relatively impermeable rock substrate. In this case, oil was entrapped in the soil matrix beneath boiler and power buildings, an area approximately 800 m^2. The project lasted from February to October 1985.

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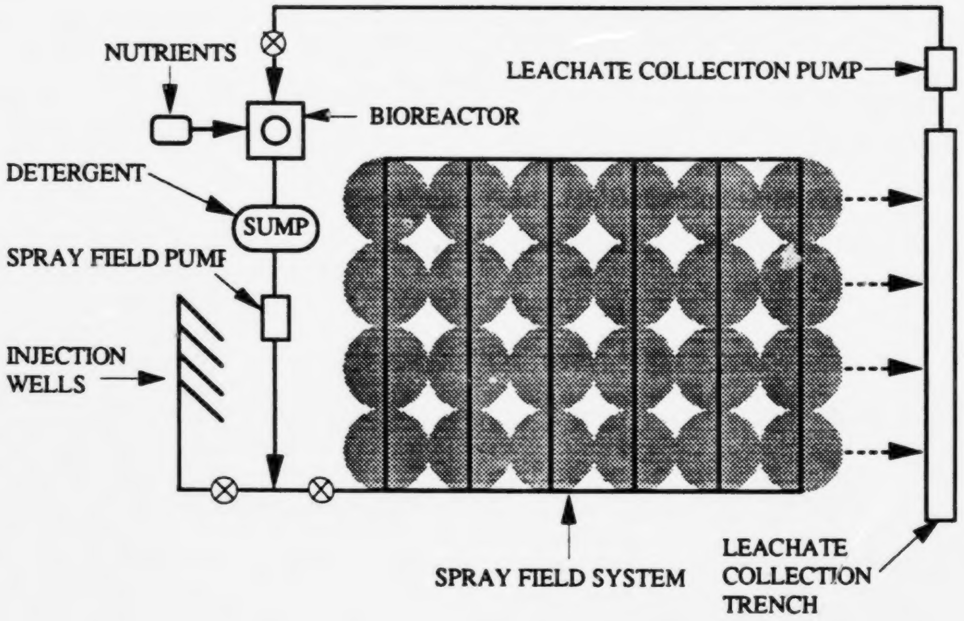
NUTRIENTS
LEACHATE COLLECITON PUMP
BIOREACTOR
DETERGENT
SUMP
SPRAY FIELD PUMF
INJECTION WELLS
SPRAY FIELD SYSTEM
LEACHATE COLLECTION TRENCH

Biodegradation

TCE in Soil and Ground Water

Technology Description

This biodegradation process has two phases: (1) use of pump and treat bioreactors to degrade trichloroethylene (TCE) and polychloroethylene (PCE) in ground water and (2) use of vegetation to encourage a rhizosphere that can degrade TCE and PCE in surface soil. The first phase has three parts: isolating microbes from TCE-contaminated soil that are capable of degrading TCE and PCE in water; optimizing the degradation capabilities of these microbe in laboratory bioreactors; and building and testing a pilot-scale (10 gpm) bioreactor at C&P Burning Rubble Pits.

One benefit from this task is that large-scale bioreactors can be used in various pump and treat scenarios of ground water to remove both TCE and other volatile and non-volatile organics. Another benefit from this task is that whenever organic chemicals contaminate surface soils, selective vegetation and cultivation techniques can be used to remediate the site in a very aesthetic and cost effective manner.

Technology Performance

This process was recently tested at DOE's Savannah River site. The results from the first task were positive:

- Bacteria was isolated from native soil that can aerobically degrade TCE;
- Propane or methane was found to stimulate TCE degradation more than several other electron donors;
- Fluidized expanded bed bioreactors, using propane or methane as a primary energy source, were 99 percent and 50 percent efficient in reducing TCE concentrations in water, respectively; and
- Other wastes were also degraded when mixed wastes were used in the reactor.

The results from the second task were also positive:

- Vegetated soil was demonstrated to oxidize TCE-contaminated soil faster than unvegetated soil or sterilized soil at the Miscellaneous Chemical Basin;
- Vegetation analysis showed no difference with normal vegetation succession for the area;
- Four of the dominant plants at the test site were compared and found to have significantly different abilities to encourage TCE degradation; and
- Phospholipid fatty acid analysis of the rhizosphere defined the physiological state of rhizosphere microbes.

Remediation Costs

Cost information is not available.

General Site Information

Biodegradation technology was tested at Savannah River Site, Miscellaneous Chemical Basin, and C&P Burning Rubble Pits to remove TCE from soil and ground water.

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Biodegradation of Lube Oil Contaminated Soils

Motor Oil in Soil

Technology Description

This treatment process requires the addition of inoculant and nutrients to the contaminated soils during disking. (The nutrients in the pilot studies have consisted of sodium acetate, minerals (potassium, magnesium, ammonium, phosphate, and sulfate ions), and Tween 80, a surfactant.) Afterward, the site is covered with plastic sheeting. The plastic sheeting must have holes to allow the transport of air.

This method is applicable for oil spills at maintenance facilities, air strips, along roadways and streets, and parking lots. Although research on the method has been directed to degradation of used lubrication oil, it should be applicable to almost any nonfunctionalized aliphatic hydrocarbon.

Technology Performance

A small-scale pilot test has been conducted at the U.S. Army Construction Engineering Laboratory in Champaign, Illinois. Noticeable reduction in contaminant concentrations were evident after four to six weeks. Pilot plots consisted of plastic tubs containing eight kilograms of contaminated soil placed outside and covered with plastic. Flask tests were conducted initially to identify optimum conditions.

Remediation Costs

Cost information is not available.

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Biological Aqueous Treatment System

Organic Compounds in Ground Water and Process Water

Technology Description

The Biotrol Aqueous Treatment System (BATS) is a patented biological treatment system that is effective for treating ground water and process water contaminated by pentachlorophenol, creosote components, gasoline and fuel oil components, chlorinated hydrocarbons, phenolics, or solvents. Other potential target waste streams include coal tar residues and organic pesticides. The technology may also be effective for treating certain inorganic compounds such as nitrates; however, this application has not yet been demonstrated. The system does not treat metals.

The BATS system uses an amended microbial mixture, i.e., a microbial population indigenous to the wastewater to which a specific microorganism has been added. This system removes the target contaminants as well as the naturally occurring background organics. Contaminated water enters a mix tank, where the pH is adjusted and inorganic nutrients are added. If necessary, the water is heated to an optimum temperature, using a heat exchanger to minimize energy costs. The water then flows to the reactor, where the contaminants are biodegraded.

The microorganisms, which perform the degradation, are immobilized in a three-cell, submerged, fixed-film bioreactor. Each cell is filled with a highly porous packing material to which the microbes adhere. For aerobic conditions, air is supplied by fine bubble membrane diffusers mounted at the bottom of each cell. The system may also run under anaerobic conditions.

As the water flows through the bioreactor, the contaminants are degraded to carbon dioxide, water, and chloride ion. The resulting effluent may be discharged to a publicly owned treatment works (POTW) or may be reused on-site. In some cases, discharge with a National Pollutant Discharge Elimination System (NPDES) permit may be possible.

Technology Performance

In 1986-87, Biotrol performed a successful nine-month pilot field test of BATS at a wood preserving facility. Since that time, several other demonstrations and commercial installations have been completed. In 1989, EPA conducted a SITE demonstration of the BATS technology at the MacGillis and Gibbs Superfund site in New Brighton, Minnesota, in which the system was operated continuously for six weeks at three different flow rates. Results from the demonstration showed that PCP was reduced to less than one ppm at all flow rates. Removal percentage was as high as 97 percent at the lowest flow rate. EPA released the Technology Evaluation Report in December 1990.

Remediation Costs

Cost information is not available.

General Site Information

The SITE demonstration of the BATS technology took place from July 24 to September 1, 1989 at the MacGillis and Gibbs Superfund site in New Brighton, Minnesota.

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Bioremediation / Vacuum Extraction

Petroleum Fuels in Soil

Technology Description

The bioremediation/vacuum extraction process decontaminates soils that have been contaminated with fuels by removing the contaminated soil and stockpiling it for treatment. This technology can be applied to soils contaminated with diesel, JP5, or other fuels that have leaked from underground storage tanks.

In order to decontaminate the stockpiled soil, it is processed through a screen to eliminate rocks greater than four inches in diameter. The screened soil is transported to a site that is protected by a 40-millileter liner with eight inches of sand base. Three feet of contaminated soil is spread along the base of the prepared pile and then a series of vacuum extraction pipes are trenched in the soil and connected to the Vacuum Extraction System (VES) blower. The VES blower provides movement of oxygen through the pile. The remaining soil is piled into a trapezoid shape about 15 feet high, 200 feet long, and 60 feet wide. Fertilizer is added, and an irrigation system is installed. Computer-controlled sensors are placed within the pile to monitor temperature, pressure, and soil moisture.

Technology Performance

The field pilot test conducted in Bridgeport, California, showed two results:

- After approximately two months of operation, the average concentration of total petroleum hydrocarbons (TPH) is 120 ppm; and

- The Navy declared the tested site was "clean" in a report prepared for the California Regional Water Quality Control Board.

Remediation Costs

Remediation costs are estimated at approximately $80 per ton of soil at the Bridgeport, California, pilot project.

General Site Information

A field pilot test was conducted at Bridgeport, California in fiscal year 1989. Full-scale implementation at the 29 Palms, California, MC Air Ground Combat Center is anticipated.

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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

Biotreatment Enhanced with Pact®/Wet Air Oxidation

Organic Contaminants in Wastewater

Technology Description

This technology is applicable to municipal and industrial wastewaters, as well as ground water and leachates containing hazardous organic pollutants. This treatment system combines two technologies: the PACT® treatment system and wet air oxidation (WAO). The PACT® system uses powdered activated carbon (PAC) combined with conventional biological treatment (e.g., an activated sludge system) to treat liquid waste containing toxic organic contaminants. The WAO technology can regenerate the PAC for reuse in the PACT® system. The system is mobile and can treat from 2,500 to 10,000 gallons of wastewater per day. Larger stationary systems, treating up to 53 million gallons per day, are already in operation. In the PACT® system, organic contaminants are removed through biodegradation and adsorption. Living microorganisms (biomass) in the activated sludge system are contained in liquid suspension in an aerated basin. This biomass removes biodegradable toxic organic compounds from the liquid waste. PAC is added to enhance this biological treatment by adsorbing toxic organic compounds.

The degree of treatment achieved by the PACT® system depends on the influent waste characteristics and the system's operating parameters. Important waste characteristics include biodegradability, absorbability, and concentrations of toxic organic compounds and inorganic compounds, such as heavy metals.

Major operating parameters include carbon dose, hydraulic retention time of the aeration basin, solids retention time of the biomass-carbon mixture, and biomass concentration in the system. Liquid wastes fed into the PACT® system should have sufficient nutrients (nitrogen and phosphorous) and biodegradable compounds to support the growth of active biomass in the aeration basin. The temperature of the waste should be in the range of 40° F to 100° F, and the influent pH should be in the range of six to nine. Solids retention times affect both the concentration and type of biomass in the system; these vary from two days to 50 days. Hydraulic retention times affect the degree of biodegradation achieved and typically range from two hours to 24 hours for relatively dilute wastes, such as contaminated ground water, and up to several days for concentrated wastes and leachate. Carbon doses vary widely, depending on the biodegradability and adsorptive characteristics of the contaminants in the waste. Higher PAC concentrations improve the settleability of the PAC-biomass mixture and reduce air stripping of volatile organic contaminants.

Excess solids (PAC with adsorbed organics, biomass, and inert solids) are removed periodically from the system through the system's clarifier (settling tank) or thickener (see Figure 1). These excess solids are routed to the WAO system reactor to regenerate the spent PAC and destroy organics remaining in the biomass. Temperatures and pressures in the WAO system will be about 480° F and 800 to 850 pounds per square inch, respectively. After treatment in the WAO system, the regenerated PAC may be separated from the ash formed from destruction of the biomass and returned to the aeration basin for reuse.

Technology Performance

The PACT® system has successfully treated a variety of industrial wastewaters, including chemical plant wastewaters, dye production wastewaters, pharmaceutical wastewaters, refinery wastewaters, and synthetic fuels wastewaters, in addition to contaminated ground water and mixed industrial/municipal wastewater. In general, the PACT® system can treat liquid wastes containing wide ranges of biochemical oxygen demand (BOD), from 10 to 30,000 parts per million (ppm), and chemical oxygen demand (COD), from 20 to 60,000 ppm. Toxic volatile organic compounds can be treated up to the level where they interfere with biomass growth, about 1,000 ppm. Treatability studies have shown that the PACT system can reduce the organics in contaminated ground water from several hundred ppm to below detection limits (parts per billion range).

Remediation Costs

Cost information is not available.

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DEPARTMENT OF THE AIR FORCE
UNITED STATES OF AMERICA
MCMXLVII

Enhanced In Situ Biodegradation of Petroleum Hydrocarbons in the Vadose Zone

Petroleum Hydrocarbons in Unsaturated Soil

Technology Description

This enhanced in situ biodegradation process is a modification of soil venting technology and treats unsaturated soils contaminated with petroleum hydrocarbons. This technology can be applied to JP-4 fuels in the vadose zone.

Bioventing technology modifies the soil venting process. Soil venting introduces large volumes of air into the soil, providing oxygen needed to enhance the biodegradation of hydrocarbon contaminants. Bioventing uses soil venting coupled with nutrient and moisture augmentation.

This technology has a number of benefits:

- A large amount of volatile organics can be removed from unsaturated soil without destroying the remaining soil;
- The contaminants are merely transferred from one phase to another and the soil venting off-gas will probably require further treatment;
- By modifying soil venting rates in conjunction with supplying nutrients and moisture to the subsurface, the in situ biodegradation of the fuel components will be enhanced; and
- This process will provide complete destruction of a large portion of the in situ contaminants and minimize the amount of off gas requiring additional treatment. This technology, however, is limited to treating soil in the unsaturated zone.

Technology Performance

The pilot-scale field test was successful:

- Under optimum conditions, approximately 80 percent hydrocarbon removal was achieved;
- Biodegradation removal rates ranged from two to 20 mg/kg of soil per day. The stabilized value averaged five mg/kg of soil per day; and
- The system was not operated long enough to determine the lower level of treatment that could be achieved.

Remediation Costs

Remediation costs are estimated at approximately $12-$15 per cubic yard of soil. This estimate assumes no off-gas treatment will be required.

General Site Information

A pilot-scale field test was conducted at POL Area B at Tyndall Air Force Base, Florida, between July 1989 and August 1990. This field study only involved four small treatment plots, approximately twenty feet by six feet by five feet deep. The site was previously used as a JP4 jet fuel storage area.

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Geolock / Bio-Drain Treatment Platform

Biodegradable Contaminants in Soils

Technology Description

The Geolock/Bio-Drain treatment platform is a bioremediation system that is installed in the soil or waste matrix. All types and concentrations of biodegradable contaminants can be treated by this system. Through direct degradation or cometabolism, microorganisms can degrade most organic substances. This technology can be adapted to the soil characteristics of the area, the concentration of contaminants, and geologic formations. The system is composed of an in situ tank, an application system, and a bottom water recovery system.

The tank, an in situ structure, is composed of high density polyethylene (HDPE), sometimes in conjunction with a slurry wall. An underlying permeable waterbearing zone facilitates the creation of ingradient water flow conditions. The tank defines the treatment area, minimizes intrusion of off-site clean water, minimizes the potential for release of bacterial cultures to the aquifer, and keeps contaminant concentration at levels that facilitate treatment. The ingradient conditions also facilitate reverse leaching or soil washing. The application system, called Bio-Drain, is installed within the treatment area. Bio-Drain delivers bacterial cultures, nutrients, and oxygen or any other proprietary chemical to the soil profile. Bio-Drain acts to aerate the soil column and any standing water. This creates an aerobic environment in the air pore spaces of the soil. The cost of installation is low, and Bio-Drains can be placed in very dense configurations.

Existing wells or new wells are used to create the water recovery system for removal of contaminated soil washing water. By controlling the water levels within the tank, reverse leaching or soil washing and the volume of off-site clean water entering the system can be controlled and minimized. This minimizes the potential for off-migration. It also creates a condition such that the direction of existing contaminants and bacterial degradation products is toward the surface. Conventional biological treatment is limited by the depth of soil aeration, the need for physical stripping, or the need to relocate the contaminated media to an aboveground treatment system. The Geolock/Bio-Drain treatment platform surpasses these limitations as well as reduces or eliminates the health risks associated with excavation and air releases from other treatment technologies. Extremely dense clays may be difficult to treat with this technology. Rock shelves or boulders may render installation impossible.

Technology Performance

EPA accepted this technology into the SITE Demonstration Program in August 1990. EPA began preparation of the Quality Assurance Project Plan and site selection.

Remediation Costs

Cost information is not available.

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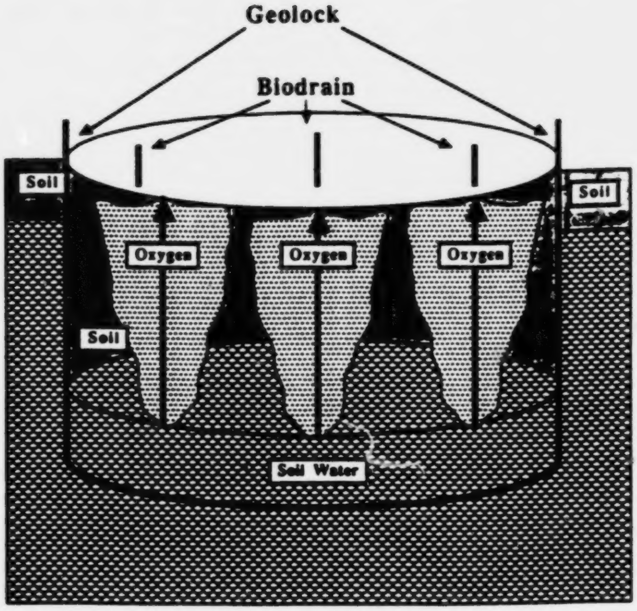
Geolock
Biodrain
Soil
Soil
Oxygen
Oxygen
Oxygen
Soil
Soil Water

In Situ Biodegradation

Fuels, Fuel Oils and Nonhalogenated Solvents in Soil and Ground Water

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Technology Description

This in situ biodegradation process treats soil or ground water contaminated with hydrocarbons such as fuels, fuel oils, and nonhalogenated solvents. This technology can be applied to fuel spills, leaky storage tanks, and fire training pits.

Nutrients (especially nitrogen and phosphorus), soil-conditioning chemicals, and hydrogen peroxide are introduced through infiltration wells, ditches, or soil surface irrigation. Pumping wells remove excess fluids or contaminated ground water. Contaminated water can be treated on the surface or reinjected for treatment in the soil. Monitoring wells must be placed within and surrounding the site. Increased fluid throughput might be accomplished by surface spray irrigation techniques. Stoichiometrically, three pounds of oxygen delivered in the hydrogen peroxide is required for each pound of hydrocarbon treated. In practice, more oxygen will be required to satisfy other demands, such as the oxidation of iron.

Technology Performance

Results from testing this technology at Kelly Air Force Base, Texas, were negative:

- Degradation of petroleum hydrocarbons was indicated;
- Although biodegradation of these compounds by indigenous bacteria had been demonstrated in laboratory scale microcosms under anaerobic and aerobic conditions respectively, this site was not ideal for this method;
- Injection wells became clogged from precipitation of calcium phosphate, which reduced their injection capacity by 90 percent; and
- This test showed that the design of hydraulic delivery systems and the compatibility of injection chemicals with soil minerals is as important to successful treatment as enhancement of bacteria.

Remediation Costs

Exclusive of site characterization, one estimate of the cost range of this method is from $100 to $200 per ton of contaminated soil. Monitoring could be expensive, depending upon the type of contaminant. Site characterization must be done to determine soil/chemical compatibility. Another estimate is that a nonresearch project would cost between $230 and $300 per gallon of residual fuel in the soil.

General Site Information

A large-scale pilot field test was conducted at Kelly Air Force Base, Texas, from May 1985 to February 1986. A large-scale pilot test is planned for a tank farm at the Naval Air Station, Patuxent River, Maryland.

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In Situ Biodegradation

Organic Compounds in Soil

Technology Description

This in situ biodegradation process reclaims contaminated soil in-place. It can be applied to organic compounds released from fuel spills, leaky storage tanks, fire training pits, and other contaminant sources.

In situ biodegradation involves the enhancement of environmental conditions that facilitate biodegradation of organic contaminants by native or exotic soil or sediment microorganisms. Aerobic degradation is normally the most efficient means by which microorganisms break down organic contaminants. Direct exposure to the atmosphere is one means to provide aerobic conditions for in situ biodegradation. For flooded or poorly drained soils or subsurface soils, it may not always be possible to provide direct exposure to atmospheric oxygen without improving drainage. In such situations, in situ biodegradation can be enhanced by providing alternate electron acceptors, such as nitrate or hydrogen peroxide, to the system. The efficiency of in situ biodegradation enhancement procedures can be tested in laboratory reactors before scale-up for field application is carried out.

Nutrients (especially nitrogen and phosphorus), soil-conditioning chemicals, and hydrogen peroxide can be introduced through infiltration wells, ditches, or soil surface irrigation. Another source of oxygen for aerobic biodegradation may be fresh air introduced during the process of soil venting for remediation of volatile organic compounds (VOCs) from the soil. Pumping wells remove excess fluids or contaminated ground water. Contaminated water can be treated on the surface or reinjected for treatment in the soil. Monitoring wells must be placed within and surrounding the site. Water requirements can be met by surface spray irrigation techniques. Although every pound of hydrocarbon contaminant requires about 10 pounds of molecular oxygen for complete degradation, in practice, more oxygen will be required to satisfy other demands, such as oxidation of iron.

This technology has numerous advantages:

- Excavation is not required;
- Resulting products are not toxic;
- Contaminant concentrations are reported to have been reduced by bacteria to less than one ppm; and
- Theoretically, in situ treatment of contaminated soil can be accomplished faster than the long-term flushing required for surface-based water treatment.

In situ biodegradation, however, also has limitations:

- High calcium, magnesium, or iron concentrations in the soils and plugging and loss of soil permeability limit the effectiveness of the method;
- The method currently is limited primarily to sandy soils having a hydraulic conductivity of at least 0.0001 cm/sec;
- Some mobilization of heavy metals can occur;
- Applicability is site-specific;
- Considerable oxygen is required; and
- Daily maintenance might be necessary if hydrogen peroxide is in the lines and pumps and if special metals are not used.

Technology Performance

Results from preliminary full-scale testing at Eglin Air Force Base, Florida, were negative:

- After 15 months of operation at this site, it was concluded that using hydrogen peroxide as an oxygen source for biodegradation has limitations which could restrict its successful application to relatively few Air Force sites.

Results from a large-scale pilot field test at Kelly Air Force Base, Texas, were mixed:

- Degradation of petroleum hydrocarbons was indicated;
- The site was not ideal for this method;
- Injection wells became clogged from precipitation of calcium phosphate, which reduced their injection capacity by 90 percent; and
- Design of hydraulic delivery systems and compatibility of injection chemicals with soil minerals is as important to successful treatment as enhancement of bacteria.

Remediation Costs

The cost varies depending on site-specific conditions. Exclusive of site characterization, one estimate of the cost range for this method is from $100 to $200 per ton of contaminated soil. Monitoring could be expensive, depending upon the type of contaminant. Site characterization must be done to determine soil/chemical compatibility. Another estimate is that a nonresearch project would cost between $230 and $300 per gallon of residual fuel in the soil.

General Site Information

This method was implemented at Eglin Air Force Base, Florida, starting in November 1986. Full-scale implementation began in early summer of 1987. In addition, a large-scale pilot field test was conducted at Kelly Air Force Base, Texas, from May 1985 to February 1986. The Waterways Experiment Station (WES) currently is assisting the US Navy in evaluation of anaerobic in situ biodegradation for cleanup of a gasoline spill from an underground tank located in a wetland area.

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In Situ Biological Treatment

Organic Constituents in Soil, Sediment, Sludge, and Water

Technology Description

Biological processes can be applied to water, soil, sludge, sediment, and other types of materials contaminated with organic constituents. This bioremediation technology is designed to biodegrade chlorinated and non-chlorinated organic contaminants by employing aerobic bacteria that use the contaminants as their carbon source. This proposed technology has two configurations: in situ biotreatment of soil and water; and on-site bioreactor treatment of contaminated ground water.

A primary advantage of in situ bioremediation is that contaminants in subsurface soils and ground water can be treated without excavating overlying soil. This technology uses special strains of cultured bacteria and naturally occurring microorganisms in on-site soils and ground water. Because the treatment process is aerobic, oxygen and soluble forms of mineral nutrients must be introduced throughout the saturated zone. The end products of the aerobic biodegradation are carbon dioxide, water, and bacterial biomass. (This system must be engineered to maintain parameters such as pH, temperature, and dissolved oxygen (if the process is aerobic), within ranges conducive to the desired microbial activity.)

Contaminated ground water can also be recovered and treated in an aboveground bioreactor. Nutrients and oxygen can then be added to some or all of the treated water, and the water can be recycled through the soils as part of the in situ soil treatment.

Because site-specific environments influence biological treatment, all chemical, physical, and microbiological factors are designed into the treatment system. Subsurface soil and ground-water samples collected from a site are analyzed for baseline parameters, such as volatile organics, metals, pH, total organic carbon, types and quantities of microorganisms, and nutrients. A treatability study, which includes flask and column studies, determines the effects of process parameters on system performance. The flask studies test biodegradation under optimum conditions, and the column studies test the three field applications: (1) soil flushing; (2) in situ biotreatment, and (3) in situ biotreatment using ground water treated in a bioreactor.

Technology Performance

The planned demonstration of this technology on a wide range of toxic organic compounds was canceled after the completion of treatability studies in April 1990. EPA released the treatability study report in January 1991. Although the demonstration was canceled at the first site, the technology may be demonstrated at another hazardous waste site in the future.

Remediation Costs

Cost information is not available.

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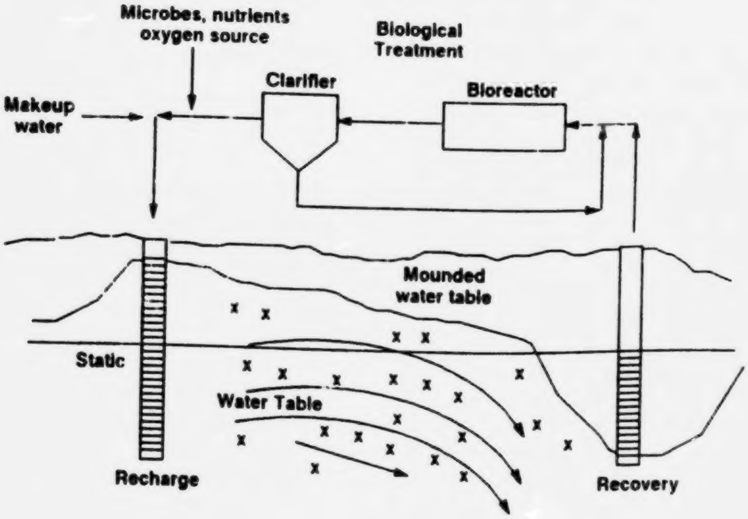
Microbes, nutrients
oxygen source
Biological
Treatment
Clarifier
Bioreactor
Makeup
water
Mounded
water table
Static
Water Table
Recharge
Recovery

In Situ Bioremediation Process

Volatile Organics in Soil

Technology Description

This in situ bioremediation process increases the quality and acceleration of biodegradation in contaminated soils. Different contaminants may have different degrees of success. High concentrations of heavy metals, non-biodegradable toxic organics, alkaline conditions, or acid conditions could interfere with the degradation process. Although volatiles may volatilize during remediation, volatilization has been minimized by adding a hood around the auger assembly and treating the captured gases. The Dual Auger System was also developed for the treatment of inorganic contaminated soils, by injecting reagent slurry into the soil to solidify/stabilize contaminated waste.

This in situ bioremediation process uses a specialized equipment system to inject site-specific microorganism mixtures, along with the required nutrients, and homogeneously mix them into the contaminated soils. The injection and mixing process effectively breaks down fluid and soil strata barriers, and eliminates pockets of contaminated soil that would otherwise remain untreated.

The process uses a twin, five-foot diameter auger system powered and moved by a standard backhoe. The auger drills into contaminated soil with hollow shafts, allowing the microorganism and nutrient mixture to pass. The allocation of the microorganisms and nutrients occurs during the initial auger action. The auger flights break the soil loose, allowing mixing blades to thoroughly blend the microorganism and nutrient mixture with the soil. This occurs in an overlapping manner to ensure the complete treatment of all contaminated soil. The mixing action is continued as the augers are withdrawn. Treatment depth can exceed 100 feet. Water, nutrients, and bacteria are added to the contaminant area as needed.

Technology Performance

EPA accepted this technology into the SITE Program in June 1990 and is currently locating a site to demonstrate this project.

Remediation Costs

Cost information is not available.

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Liquid/Solid Contact Digestion

Organic Materials in Soil and Sludge

Technology Description

Remediation Technologies (formerly Motec, Inc.) has developed a liquid-solid contact digestion (LSCD) process which biodegrades liquids, sludges, and soils with high organic concentrations. Specifically, this technology can treat halogenated and nonhalogenated organic compounds, including some pesticides and herbicides. In this process, organic materials and water are placed in a high energy environment, in which acclimated microorganisms biodegrade the organic constituents.

The system consists of two or three portable tank digesters or lagoons: (1) a primary contact or mixing tank; (2) a primary digestion tank; and (3) a polishing tank. Treatment may take ten days or more, depending on the type and concentration of the contaminants and the temperature in the tanks.

In the primary contact tank, water is mixed with influent sludge or soil. The mixing process is designed to achieve a 20 to 25 percent solids concentration. Water is obtained either from the contaminated source or a fresh water source. Emulsifying chemicals may be added and pH is adjusted to increase the solubility of the organic phase. After water is added, the batch mixture is transferred to the primary digestion tank, where acclimated seed bacteria are added and aerobic biological oxidation is initiated. Most of the biological oxidation occurs during this phase.

When the biodegradation reactions decrease significantly, the batch mixture is transferred to the polishing tank for final treatment. Once the pH has been readjusted in the polishing cell, co-metabolites and nutrients are added to maintain and enhance the biomass. In this phase, organic constituents are degraded to target concentration levels. Because the system runs on a negative water balance, water is added throughout the process. Once target levels are reached, the supernatant from the polishing tank is recycled to the primary contact tank and biological sludge is treated in prepared bed solid phase bioreactors.

Technology Performance

This technology has not been demonstrated to date. The developer is seeking private party co-funding for a three- to four-month demonstration on petroleum or coal tar-derived wastes.

Remediation Costs

Cost information is not available.

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Submerged Aerobic Fixed-Film Reactor

Biodegradable Materials in Liquid

Technology Description

This biological treatment system relies on aerobic microbial processes to metabolize contaminants present in a liquid waste stream. This system can treat liquid waste containing low concentrations (less than 20 ppm) of readily biodegradable materials and yield concentrations in the low parts per billion (ppb) range.

This technology is typically used to treat ground water and industrial process waters, but is also applicable to contaminated lagoon and/or pond waters. The water to be treated must fall within a pH of 6.5 to 8.5, a temperature of 60-90°F, and be free of toxic and/or inhibitory metals. Readily biodegradable compounds, such as methyl ethyl ketone and benzene can be treated, along with some organic chemicals that are initially more resistant to biodegradation, such as chlorobenzene. Halogenated compounds are not readily biodegraded and cannot be treated by this system.

This system consists of an above-ground fixed-film reactor, supplemental nutrient storage tank and pump, cartridge filter, and final activated-carbon filter. High surface area plastic media is used to fill the reactor and the water level within the reactor is set to cover the plastic media. Bacterial growth is attached as film to the surface of the plastic media.

The bioreactor is operated on a one-pass, continuous-flow basis at hydraulic retention times as low as one hour. The process begins when contaminated water from a well or equalization tank is pumped into the bioreactor. The influent waste stream is evenly dispersed over the reactor packing by a header-distribution system. As the waste stream passes through the reactor, the biofilm removes the biodegradable organics. An air distribution system below the plastic media supplies oxygen to the bacteria in the form of fine bubbles. An effluent water header system collects water from the reactor after is has been treated. Water exiting the reactor is first passed through a cartridge filter, to remove any excess biological solids, followed by activated carbon treatment, to further remove any remaining organic compounds. Depending upon the effluent water discharge criteria, the cartridge and carbon filters may not be needed.

Technology Performance

The demonstration for this treatment system is expected to start in the spring or summer of 1991.

Remediation Costs

Cost information is not available.

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DEPARTMENT OF THE ARMY UNITED STATES OF AMERICA 1775

TNT Slurry Reactor

Explosives (TNT, RDX, HMX) in Soil

Technology Description

In this treatment, a slurry of TNT-contaminated soils and water are bio-treated in a thoroughly mixed environment. Loss transfer effects, as well as biological conditions are controlled via mixing rate, oxygen, and nutrient addition. Reactor designs being considered include a knife blade slurry reactor and rotary sequencing batch reactors (SBRs). Work includes culture microbe studies of TNT degraded using C^{14} tracers. This treatment may be applied to soils contaminated with TNT, RDX, HMX, and other potential wastes associated with explosives.

Technology Performance

A bench-scale study has been performed. A demonstration and feasibility study was scheduled at Argonne National Laboratory in fiscal year (FY) 1990.

Remediation Costs

Cost information is not available.

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DEPARTMENT OF ENERGY
UNITED STATES OF AMERICA

U1/U2 Ground-Water Biological Treatment Demonstration

Nitrates and Organics in Ground Water and Wastewater

Treatment Description

This biological treatment system simultaneously removes nitrates and organics from contaminated aqueous streams. This technology can be applied to ground water and wastewater.

Biodenitrification is a technology for the simultaneous removal of nitrates and organics from contaminated aqueous streams. At Hanford, the U1/U2 Groundwater Biological Treatment Project will demonstrate a biological process for simultaneous destruction of nitrates and specific organic contaminants in Hanford ground waters.

The treatment process uses facultative anaerobic microorganisms isolated from the Hanford Site that have been shown to degrade both nitrates and carbon tetrachloride. These contaminants have been identified in U1/U2 ground water from the 200 West Area of the Hanford Site at levels exceeding the drinking water standard.

Treatment Performance

Results from demonstrations at the Hanford Site were positive:

- Based on tests with a simulated ground water feed, greater than 99 percent of the nitrates and 93 percent of the carbon tetrachlorides were destroyed at influent concentrations of 400 ppm and 200 ppb, respectively; and
- Analysis of the product streams indicated that the concentrations of nitrates and carbon tetrachlorides were below the drinking water standards of 44 ppm and 5 ppb, respectively.

Remediation Costs

Cost information is not available.

General Site Information

This process was demonstrated with a simulated ground water feed in fiscal year (FY) 1989 and will be demonstrated at the Hanford Site, Washington, in FY 1991. Liquid wastes containing radioactive, hazardous, and regulated chemicals have been generated throughout the 40 years of operations on the Hanford Site. Some of these wastes were discharged to the soil column and many of the waste components, including nitrates and carbon tetrachloride, have been detected in the Hanford ground water.

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Chemical Treatment

Chemical Detoxification of Chlorinated Aromatic Compounds

Dioxin and Herbicides in Soil

Treatment Description

This chemical detoxification of chlorinated aromatic compounds detoxifies soils that have been contaminated with dioxin, herbicides or other chlorinated aromatic contaminants.

The contaminated soil is excavated and a determination of the water content is made. If the water content is too high, the soil is dehydrated. Soil is placed in the reactor with the reagent and heated to 100 to 150 degrees Celsius. The reagent is a 1:1:1 mixture of potassium hydroxide, polyethylene glycol, and dimethyl sulfoxide. After reaction, the reactor is drained and the soil is rinsed with clean water to remove excess reagents. Treated soil might be replaced in its original location depending upon the effectiveness of the decontamination and local environmental regulations.

Technology Performance

Demonstrations of this method achieved greater than 99.9 percent decontamination. Several advantages of this method were indicated:

- It is relatively inexpensive for contaminants at low concentrations (in the ppm range);
- The reagents can be recycled;
- The products of the decontamination are not toxic and are not biodegradable;
- Bioassay studies show that the reaction products do not bioaccumulate or bioconcentrate, they do not cause mutagenicity, nor are they toxic to aquatic organisms or mammals;
- The chlorine atoms are replaced by glycol chains producing non-toxic aromatic compounds and inorganic chloride compounds; and
- The equipment components are commercially available.

Despite the numerous advantages of this technology, it also has limitations:

- For high contaminant concentrations in the percent range, incineration could be less expensive to use;
- Water might interfere with the reactions between the reagents and the chlorinated aromatic compounds; and
- Some chlorinated compounds, such as hexachlorophene 24, are not degraded as effectively as others.

Remediation Costs

The costs are in the range of $100 to $200 per ton. The Naval Civil Engineering Laboratory (NCEL) reports that the costs might be on the order of $300 per cubic yard. The most expensive item is the reagent.

General Site Information

Small-scale pilot testing (one to ten drums) has been conducted on dioxin- contaminated soil by the Air Force in the laboratory. Larger-scale pilots are planned for the near future by the EPA at Edison, New Jersey. A large-scale pilot (less than ten drums) for PCB decontamination is scheduled for testing in January 1988 in Guam. The pilot will treat about 30 cubic yards to determine cost effectiveness and develop design criteria. Full-scale implementation is scheduled for the end of 1988. The pilot reactor has a capacity of two cubic yards. The capacity of the full-scale reactor will be 20 to 30 cubic yards.

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Chemical Oxidation/Cyanide Destruction

Organics and Cyanide in Water, Soils, and Sludges

Technology Description

This treatment system uses chlorine dioxide, generated on-site by a patented process, to oxidize organically contaminated aqueous waste streams, and simple and complex cyanide in water or solid media. Chlorine dioxide is an ideal oxidizing agent because it chemically alters contaminants to salts and non-toxic organic acids. This technology is applicable to aqueous wastes, soils, or any leachable solid media contaminated with organic compounds. This technology also is applicable to ground water contaminated with pesticides or cyanide; sludges containing cyanide, pentachlorophenol (PCP) or other organics; and industrial wastewater similar to refinery wastewater.

Chlorine dioxide gas is generated by reacting sodium chlorite solution with chlorine gas, or by reacting sodium chlorite solution with sodium hypochlorite and hydrochloric acid. Both processes produce at least 95 percent pure chlorine dioxide.

In aqueous treatment systems the chlorine dioxide gas is fed into the waste stream via a venturi, which is the driving force for the generation system. The amount of chlorine dioxide required depends on the contaminant concentrations in the waste stream and the concentration of oxidizable compounds, such as sulfides.

In soil treatment applications, the chlorine dioxide may be applied in situ via conventional injection wells or surface flushing. The concentration of chlorine dioxide would depend on the level of contaminants in the soil.

Chlorine dioxide treatment systems have been applied to drinking water disinfection, food processing sanitation, and as a biocide in industrial process water. Since chlorine dioxide reacts via direct oxidation rather than substitution (as does chlorine), the process does not form undesirable trihalomethanes.

Technology Performance

The SITE program has accepted two proposals from Exxon Chemicals, Inc. and Rio Linda Chemical Company to perform two separate demonstrations: one of cyanide destruction and the other of organics treatment. Site selection for these demonstrations is currently underway.

Remediation Costs

Cost information is not available.

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Combined Chemical Binding / Precipitation and Physical Separation of Radionuclides

Radionuclides and Heavy Metals in Water, Sludges or Soils

Technology Description

This chemical binding and physical separation method involves rapid, turbulent, in-line mixing of a proprietary fine powder (RHM 1000) containing complex oxides and other reactive binding agents. RHM 1000 absorbs, adsorbs, and chemisorbs most radionuclides and heavy metals in water, sludges, or soils (pre-processed into slurry), yielding coagulating, flocculating and precipitating reactions. The amount of RHM 1000 required for processing ranges from 0.1 percent to less than 0.01 percent, depending on the application. The pH, mixing dynamics, and processing rates are carefully chosen to optimize the binding of contaminants.

Water is separated from the solids using a reliable, economical, two-stage process based on two processes: (1) particle size and density separation, using clarifier technology and microfiltration of all particles and aggregates; and (2) dewatering, using a filter press, to produce a 70 to 85 percent dry filter cake with the concentrated radionuclide(s), heavy metal(s), and other solids. The filter cake is collected and stabilized for disposal.

The process is designed for continuous throughput for water (50-1500 gal/min) or batch mode sludge and soil processing (300 tons per eight-hour day). This technology can accommodate trace levels, naturally occurring radioactive materials (NORM), and low-level radioactive wastes. The equipment is trailer-mounted for use as a mobile field system. Larger capacity systems could be skid-mounted.

This technology can be used for most radionuclides and heavy metals in water, sludges, or soils: (1) cleanup and remediation of water, sludges, and soils contaminated with radium, thorium, uranium and heavy metals from uranium mining/milling operations; (2) cleanup of water containing NORM and heavy metals from oil and gas drilling; and (3) cleanup and remediation of man-made radionuclides stored in underground tanks, pits, ponds, or barrels. This technology is not applicable to water containing tritium.

Treatment Performance

EPA accepted this technology into the SITE Demonstration Program in July 1990. The Department of Energy (DOE) is working with EPA to evaluate the TechTran's chemical binding and physical separation process.

Remediation Costs

Cost information is not available.

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Thermal Treatment

Centrifugal Reactor

Metals and Organic Compounds in Soils and Sludges

Technology Description

The Centrifugal Reactor is a thermal treatment technology that uses heat from a plasma torch to create a molten bath that detoxifies soils and sludges contaminated with metals and hard-to-destroy organic compounds. Developed by Retech, Inc., this technology vaporizes organic contaminants at very high temperatures to form innocuous products. The technology melts solids and incorporates them into the molten bath. When cooled, the result is a non-leachable matrix that immobilizes the metals.

Contaminated soils enter the reactor through a bulk feeder. The interior of the reactor (the reactor well) rotates during waste processing. Centrifugal force created by this rotation prevents waste and molten material from flowing out of the reactor through the bottom. It also helps to transfer heat and electrical energy evenly throughout the molten phase. Periodically, a fraction of the molten slag is tapped and falls into the collection chamber to solidify.

Gases travel through the secondary combustion chamber, where they remain at a high temperature for an extended period of time. This allows for further thermal destruction of any organics remaining in the gas phase. Downstream of the secondary combustion chamber, the gases pass through a series of air pollution control devices designed to remove particulates and acid gases. In the event of a process upset, a surge tank has been installed to allow for the reprocessing of any off-gases produced.

Technology Performance

A demonstration is planned for late 1991 at a Department of Energy research facility in Butte, Montana. During the demonstration, the reactor will process approximately 4,000 pounds of waste at a feed rate of 100 pounds per hour. All feed and effluent streams will be sampled to assess the performance of this technology. A report on the demonstration project will be available after its completion.

Remediation Costs

Cost information is not available.

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Circulating Bed Combustor

Halogenated and Non-Halogenated Hydrocarbons in Soils, Slurries, and Sludges

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Technology Description

The Ogden Circulating Bed Combustor (CBC) uses high velocity air to entrain circulating solids and create a highly turbulent combustion zone for the efficient destruction of toxic hydrocarbons. The CBC technology is applicable to soils, slurries, and sludges contaminated with halogenated and nonhalogenated hydrocarbons. This technology was recently applied at two site remediation projects for treating soils contaminated with polychlorinated biphenyls (PCBs) and fuel oil. The CBC is one of seven incinerators permitted to burn PCBs.

The Ogden CBC operates by feeding waste material and limestone into the combustion chamber along with the recirculating bed material from the hot cyclone. The limestone neutralizes acid gases. Hot gases produced during combustion pass through a convective gas cooler and baghouse before being released to the atmosphere. The treated ash is transported out of the system by an ash conveyor for proper disposal.

The CBC technology operates at relatively low temperatures (approximately 1600° F), thus reducing operation costs. The high turbulence produces a uniform temperature around the combustion chamber, hot cyclone, and return leg. It also promotes the complete mixing of the waste material during combustion. The effective mixing and relatively low combustion temperature also reduce emissions of carbon monoxide and nitrogen oxides.

Technology Performance

The commercial-size combustion chamber (36 inches in diameter) at the McColl Superfund site can treat up to 100 tons of contaminated soil daily, depending on the heating value of the feed material. Ogden states that the CBC technology can attain a destruction and removal efficiency (DRE) of 99.99 percent for hazardous waste and 99.9999 percent for PCB waste.

Remediation Costs

Cost information is not available.

General Site Information

A test burn/treatability study of waste from the McColl Superfund site was conducted in March 1989. EPA is currently reviewing results from this pilot-scale demonstration.

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Desorption and Vapor Extraction System

Volatile and Semivolatile Organics and Volatile Inorganics in Soils, Sediments, and Sludges

Technology Description

The Desorption and Vapor Extraction System (DAVES) uses a low-temperature, fluidized bed to remove volatile and semivolatile organics, including polychlorinated biphenyls (PCBs), polynuclear aromatic hydrocarbons (PAHs), pentachlorophenol (PCP), volatile inorganics (tetraethyl lead), and some pesticides from soil, sludge, and sediment. In general, the process treats waste containing less than 5 percent total organic contaminants and 30 to 90 percent solids. Nonvolatile inorganic contaminants (such as metals) in the waste feed do not inhibit the process, but are not treated.

Contaminated materials are fed into a co-current, fluidized bed, where they are well mixed with hot air (about 1,000 to 1,400° F) from a gas-fired heater. Direct contact between the waste material and the hot air forces water and contaminants from the waste into the gas stream at a relatively low fluidized-bed temperature (about 320 ° F). The heated air, vaporized water and organics, and entrained particles flow out of the dryer to a gas treatment system.

The gas treatment system removes solid particles, vaporized water, and organic vapors from the air stream. A cyclone separator and baghouse remove most of the particulates in the gas stream from the dryer. Vapors from the cyclone separator are cooled in a venturi scrubber, counter-current washer, and chiller section before they are treated in a vapor-phase carbon adsorption system. The liquid residues from the system are centrifuged, filtered, and passed through two activated carbon beds arranged in series.

By-products from the DAVES treatment include: (1) approximately 96 to 98 percent of solid waste feed as clean, dry solid; (2) a small quantity of centrifuge sludge containing organics; (3) a small quantity of spent adsorbent carbon; (4) wastewater that may need further treatment; and (5) small quantities of baghouse and cyclone dust.

Technology Performance

EPA is currently selecting a demonstration site for this process. The wastes preferred for the demonstration are harbor or river sediments containing at least 50 percent solids and contaminated with PCBs and other volatile or semivolatile organics. Soil with these characteristics may also be acceptable. About 300 tons of waste are needed for a two-week test. The demonstration may potentially be held at the selected demonstration site or wastes may be transported to a facility in Arizona that is owned by the developer. Major test objectives are to evaluate feed handling, decontamination of solids, and treatment of gases generated by the process.

Remediation Costs

Cost information is not available.

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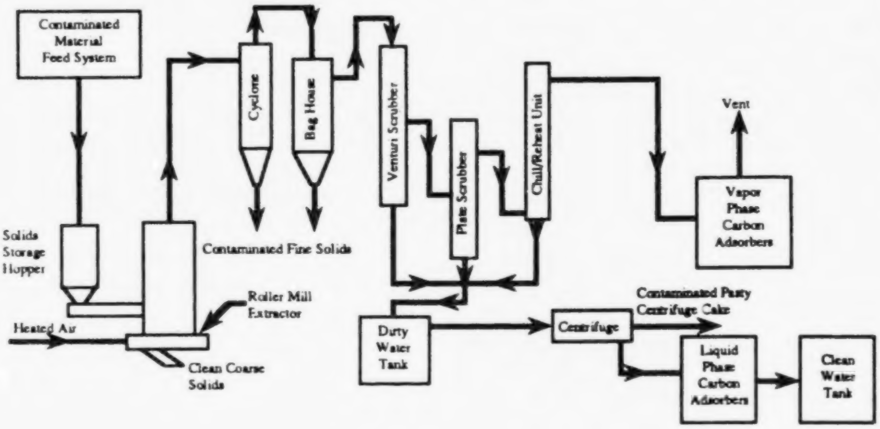
Contaminated Material Feed System
Cyclone
Bag House
Venturi Scrubber
Plate Scrubber
Chill/Reheat Unit
Vent
Vapor Phase Carbon Adsorbers
Solids Storage Hopper
Contaminated Fine Solids
Roller Mill Extractor
Heated Air
Clean Coarse Solids
Dirty Water Tank
Centrifuge
Contaminated Pasty Centrifuge Cake
Liquid Phase Carbon Adsorbers
Clean Water Tank

Flame Reactor

Volatile and Nonvolatile Metals in Solids, Soils, Flue Dusts, Slags, and Sludges

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Technology Description

This Flame Reactor process is a patented, hydrocarbon-fueled, flash smelting system that treats residues and wastes containing metals. The Flame Reactor has been successfully tested using electric arc furnace dust, lead blast furnace slag, iron residues, zinc plant leach residues and purification residues, and brass mill dusts and fumes. Metal bearing wastes previously treated contained zinc (up to 40 percent), lead (up to 10 percent), cadmium (up to 3 percent), chromium (up to 3 percent), as well as copper, cobalt, nickel and arsenic.

The reactor processes wastes with a very hot (greater than 2000° C) reducing gas produced from the combustion of solid or gaseous hydrocarbon fuels in oxygen-enriched air. In a compact, low-capital cost reactor, the feed materials react rapidly, allowing a high waste throughput. The end products are a non-leachable slag (a glasslike solid when cooled) and a recyclable, heavy metal-enriched oxide. The volume reduction achieved (of waste to slag) depends on the chemical and physical properties of the waste.

This Flame Reactor technology applies specifically to granular solids, soil, flue dusts, slags, and sludges containing heavy metals. The volatile metals are fumed and captured in a product dust collection system, the nonvolatile metals are encapsulated in the slag. At the elevated temperature of the Flame Reactor technology, organic compounds are destroyed. In general, the process requires that wet agglomerated wastes be dry enough (up to 15 percent total moisture) to be gravity-fed and fine enough (less than 200 mesh) to react rapidly. Larger particles (up to 20 mesh) can be processed; however, a decrease in the efficiency of metals recovery usually results.

Technology Performance

The Flame Reactor demonstration plant at Monaca, Pennsylvania, has a capacity of 1.5 to 3.0 tons/hour. A SITE demonstration is scheduled to be conducted at the Monaca facility under a RCRA RD&D permit that will allow the treatment of Superfund wastes containing high concentrations of metals, but only negligible concentrations of organics. The major objectives of the SITE technology demonstration are to evaluate: (1) the levels of contaminants in the residual slag and their leaching potential; (2) the efficiency and economics of processing; and (3) the reuse potential for the recovered metal oxides. Approximately 120 tons of contaminated materials are needed for the test. The most likely candidate wastes include mine tailings or smelting waste such as slag, flue dust, and wastewater treatment sludges. Pretreatment may be required to produce a dryer feed and to reduce the particle size.

Remediation Costs

Cost information is not available.

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Infrared Thermal Destruction

Organic Compounds, PCBs and Metals in Soil

Technology Description

This electric infrared incineration technology (originally developed by Shirco Infrared Systems, Inc. of Dallas, Texas) is a mobile thermal processing system that is suitable for soils or sediments contaminated with organic compounds, polychlorinated biphenyls (PCBs), and metals. Liquid organic wastes can be treated after mixing with sand or soil.

This technology uses electrically-powered silicon carbide rods to heat organic wastes to combustion temperatures. Any remaining combustibles are incinerated in an afterburner. One configuration for this mobile system is comprised of four components: an electric-powered infrared primary chamber, a gas-fired secondary combustion chamber, an emissions control system, and a control center.

The infrared incineration technology process operates by feeding waste into the primary chamber on a wire-mesh conveyor belt and exposing the waste to infrared radiant heat (up to 1850° F) provided by the horizontal rows of electrically-powered silicon carbide rods above the belt. A blower delivers air to selected locations along the belt and can be used to control the oxidation rate of the waste feed. The ash material that drops off the belt in the primary chamber is quenched using scrubber water effluent. The ash is then conveyed to the ash hopper, where it is removed to a holding area and analyzed for PCB content.

Volatile gases from the primary chamber flow into the secondary chamber, which uses higher temperatures, greater residence time, turbulence, and supplemental energy (if required) to destroy these gases. Gases from the secondary chamber are ducted through the emissions control system. In the emissions control system, the particulates are removed in a venturi scrubber. Acid vapor is neutralized in a packed tower scrubber. An induced draft blower draws the cleaned gases from the scrubber into the free-standing exhaust stack. An emergency stack is installed prior to the venturi scrubber system so that if the temperature control system and its interlocks fail, the emissions control system will not be melted by the hot gases. The scrubber liquid effluent flows into a clarifier, where scrubber sludge settles out for disposal, and through an activated carbon filter for reuse or to a publicly-owned treatment work (POTW) for disposal.

Technology Performance

EPA has conducted two Superfund Innovative Technology Evaluation (SITE) demonstrations for the infrared thermal destruction technology. The first demonstration was conducted at the Peak Oil site in Tampa, Florida and the second demonstration was performed at the Rose Township-Demode Road site in Michigan. The results of the two SITE demonstrations and eight other case studies are summarized below:

- In both tests, at standard operating conditions, PCBs were reduced to less than one ppm in the ash, with a destruction and removal efficiency destruction and removal efficiency (DRE) for air emissions greater than 99.99 percent (based on detection limits).
- In the pilot-scale demonstration, the Resource Conservation and Recovery Act (RCRA) standard for particulate emission (180 mg/dscf) was achieved. In the full-scale demonstration, however, this standard was not met in all runs due to scrubber inefficiencies.
- Lead was not immobilized; however, most lead remained in the ash and only in significant amounts were transferred to the scrubber water or emitted to the atmosphere.

- The pilot testing demonstrated satisfactory performance, with a high feed rate and reduced power consumption, when fuel oil was added to the waste feed and the primary chamber temperature was reduced.

- The process is capable of meeting both RCRA and Toxic Substances Control Act (TSCA) DRE requirements for air emissions. Operations on waste feed contaminated with PCBs have consistently met the TSCA guidance level of two ppm in ash;

- Improvements in the scrubber system resulted in compliance with RCRA and TSCA particulate emission standards. In some cases, restrictions in chloride levels in the waste and/or feed rate may be necessary to meet particulate emissions standards; and

Data evaluated during the SITE Application Analysis suggest that additional preprocessing may be needed to meet suitable ranges for various waste characteristics:

- Particle size, 5 microns to 2 inches;
- Moisture content, up to 50 percent (wt.);
- Density, 30-130 lb/cf;
- Heating value, up to 10,000 Btu/lb;
- Chlorine content, up to 5 percent (wt.);
- Sulfur content, up to 5 percent (wt.);
- Phosphorus, 0-300 ppm;
- pH, 5-9; and
- Alkali metals, up to 1 percent (wt.).

Remediation Costs

Economic analysis and observation of the test results suggest a cost range from $180/ton to $240/ton of waste feed, excluding waste excavation, feed preparation, profit, and ash disposal costs. Overall costs may be as high as $800/ton.

General Site Information

EPA conducted two evaluations of the infrared system. EPA conducted a full-scale unit evaluation from August 1 to 4, 1987, during a removal action by Region IV at the Peak Oil site, an abandoned oil refinery in Tampa, Florida. During the cleanup, a nominal 100-ton per day system treated nearly 7,000 cubic yards of waste oil sludge containing PCBs and lead. A second demonstration of the system, at pilot scale, took place at the Rose Township-Demode Road site, a National Priority List (NPL) site in Michigan, from November 2 to 11, 1987. The pilot-scale operation allowed the evaluation of performance under varied operating conditions. Infrared incineration was also used to remediate PCB-contaminated materials at the Florida Steel Corporation Superfund site and the LaSalle Electric NPL site in Illinois.

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DEPARTMENT OF THE ARMY
UNITED STATES OF AMERICA
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Low-Temperature Thermal Stripping

Volatile Organic Compounds in Soil

Technology Description

Low-temperature thermal stripping of volatile organic compounds (VOC) from soils removes volatile components such as chlorinated solvents and fuels. It can be applied to contaminated soils associated with fire training pits, burn pits, spills, and lagoons. Contaminants having boiling points as high as 500 degrees Celsius have been removed from soils.

During this process, a direct-fired boiler heats a heat transfer fluid. The heated fluid then passes through the shaft and flights of an auger and through the trough jacket surrounding the auger. Contaminated soil is introduced to the auger and trough by a feed hopper that has a rotary valve to ensure air-tight operation. Preheated air or an inert gas is passed over the auger and sweeps the volatilized contaminants to the treatment system.

This method does, however, have a number of limitations: this is a media transfer technique rather than a destructive technique; treatment of the gaseous effluent prior to discharge might be required, depending upon local regulations; bench-scale evaluation should be conducted before pilot testing or implementation; the equipment for the bench-scale test is available and will fit in a standard laboratory hood; lower explosive limits must be considered when treating soils contaminated with flammable solvents; an inert gas such as nitrogen might be considered as an alternative to air to reduce the risk of combustion or explosion; and since this is a low-temperature method, metal contaminants will not be removed.

Technology Performance

The results from this technology at Letterkenny Army Depot were extremely positive in that more than 99.9 percent of the total volatile organic compounds were removed from the soil.

Remediation Costs

To treat a site containing 15,000 to 80,000 tons of contaminated soil, the optimally sized process costs would range from $74/ton to $160/ton, respectively, without flue gas treatment. If afterburner exhaust gases are treated prior to discharge, the respective costs range from $87/ton to $184/ton.

General Site Information

A large-scale pilot test (> 10 drums) was conducted at Letterkenny Army Depot, Chambersburg, PA. The contaminants were primarily trichloroethylene, and xylene. More than 99.9 percent of the total volatile organic compounds were removed from the soil. Bench-scale tests were also conducted on soils contaminated with JP-4 and No.2 fuel oil, but the results from these tests are not yet available.

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Low Temperature Thermal Treatment (LT^3)

JP-4 and Other VOCs in Soil

Technology Description

Low Temperature Thermal Treatment (LT^3) is a demonstrated ex-situ process that provides evaporation of VOCs from contaminated soil without heating the soil matrix to combustion temperatures. The primary element is the thermal processor, an indirect heat exchanger used to dry and heat contaminated soils, thus stripping the moisture and VOCs from the soil. A demonstration was designed to test the LT^3 System by attempting to remove jet propulsion fuel (JP-4) and chlorinated organic compounds, such as trichloroethene (TCE), from contaminated soil. The only modification to the basic LT^3 was the addition of a scrubber system to control acid gas emissions.

The LT^3 Process can be best described by separating the system into three main components: soil treatment, emissions control, and water treatment. The soil treatment process involves soil being fed into the thermal processor (heat is provided by the self-contained hot-oil system burner), where the VOCs in the soil are vaporized and are drawn by an induced-draft fan. Water is sprayed on the processed soil to provide cooling and to minimize dust emissions. Processed soil is stored in an enclosed dump truck for transportation to a soil staging area.

The emission control system involves several steps. A fabric filter is used to remove particulates from the vapor drawn by the induced draft fan. Particulates are removed from the filter and added to the contaminated soils for reprocessing. An air-cooled condenser is used to remove condensable water vapor and organics from the exhaust gas. Condensed liquid is pumped into the water treatment system. The process gases from the condenser pass through an afterburner to destroy organics that remain in the exhaust. A continuous emissions monitoring system monitors afterburner exhaust for oxygen, carbon monoxide, carbon dioxide, and total hydrocarbons. Gases entering the scrubber are cooled to saturation temperature, and acidic gases are neutralized.

Liquid exiting the condenser is collected and pumped to a gravity operated oil/water separator. Light organics are removed by a skimmer; water is syphoned off. Heavy liquids, such as TCE, are syphoned with the water and later filtered in the carbon system. The organics are stored in 55 gallon drums for off-site disposal. The water is directed through two carbon adsorption units for removal of soluble organics. After leaving this system, the water is stored in a fresh water tank, to be used later in dust control. No water is discharged from the LT^3 system.

Technology Performance

Remedial investigation reports from the Tinker Air Force Base site in Oklahoma City, Oklahoma indicate that the contamination was extensive and varied in composition. The feed soil contamination levels and cleanup goals identified for some contaminants were: average TCE concentration - 743,270 ug/kg, cleanup goal - 70 ug/L; average total xylenes - 13,044 ug/kg, cleanup goal - 150 ug/L; and average toluene concentrations - 39,341 ug/kg, cleanup goal - 330 ug/L.

The demonstration showed conclusively that the LT^3 technology was effective in reducing the concentration of not only JP-4 but also all compounds originally specified in the Test Plan. All goal cleanup levels could be met by heating the processed soil above 215° F. This was a considerably lower temperature than anticipated. As a result, all goal cleanup levels were met while processing soil at rates 25 percent in excess of the design capacity. The treatment capacity was 18,000 - 20,000 lbs per hour.

Although an evaluation of the effectiveness of stripping agents in the removal of the compounds was an original objective, this was not accomplished. The demonstration was discontinued when polychlorinated biphenyls (PCBs) were discovered in the feed and processed soils because the system was not designed to process PCBs. Although definitive stack testing was not conducted to verify system performance, all Federal, State, and local emissions standards, as specified in the permit, were believed to have been met.

Remediation Costs

The unit cost for processing and decontaminating soil with similar contaminants is $86.00 per ton of soil at an average processing rate of 8 tons per hour. Total estimated costs, including mobilization and demobilization, to process 5,000 tons would be $116.00 per ton. Fixed costs for mobilization, start up, and demobilization are approximately $150,000.00.

General Site Information

This full-scale demonstration was conducted at Tinker Air Force Base in Oklahoma City, Oklahoma. The demonstration was conducted between July 17 and August 18, 1989. The feed soils were excavated from the Landfill 3 sludge dump area, which received waste oils and liquids from industrial operations at Tinker Air Force Base between 1961 and 1968.

Four types of materials were encountered in the Landfill 3 sludge area: overburden, or fill; crumbled asphalt mixed with clay; a sludge marbled with native clay; and a dry red clay. At no time was water or a saturated layer encountered at depths of less than 14 feet. The sludge/clay layer (with a strong solvent odor) was found to be the source of contamination. This layer was found at a depth of 2 to 15 feet below surface, and was 1 to 12 feet thick. A total of 3,000 cubic yards of material was excavated during the operation.

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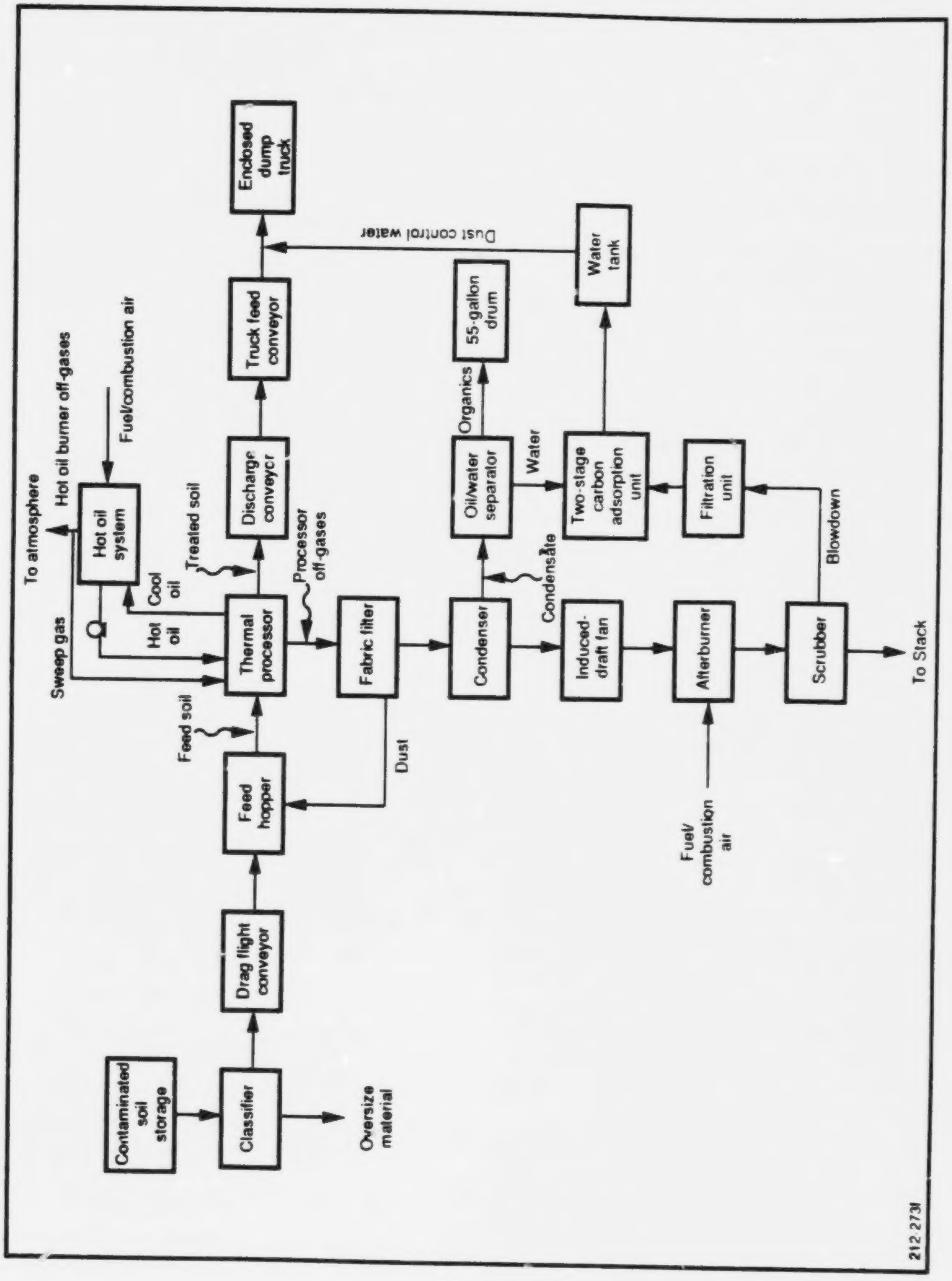
Contaminated soil storage
Classifier
Oversize material
Drag flight conveyor
Feed hopper
Dust
Feed soil
Thermal processor
Sweep gas
Hot oil
Cool oil
Hot oil system
To atmosphere
Hot oil burner off-gases
Fuel/combustion air
Treated soil
Discharge conveyor
Truck feed conveyor
Enclosed dump truck
Dust control water
Processor off-gases
Fabric filter
Condenser
Condensate
Oil/water separator
Organics
55-gallon drum
Water
Two-stage carbon adsorption unit
Water tank
Induced-draft fan
Afterburner
Fuel/ combustion air
Scrubber
Blowdown
Filtration unit
To Stack
212 2731

Pyretron® Oxygen Burner

Hazardous Organics in Solids, Sludges, and Liquids

Technology Description

The Pyretron® technology uses advanced fuel injection and mixing concepts to burn solid wastes contaminated with hazardous organics. Specifically, the Pyretron® oxygen-air-fuel burner incinerates pure oxygen combined with air and natural gas, destroying solid hazardous waste in the process. The burner operation is computer-controlled to automatically adjust the amount of oxygen to sudden changes in the heating value of the waste.

The burner can be fitted onto any conventional combustion unit for burning liquids, solids and sludges. Solids and sludges can be co-incinerated when the burner is used in conjunction with a rotary kiln or similar equipment. In general, the technology is applicable to any waste that can be incinerated. However, the technology is not suitable for processing aqueous wastes, RCRA heavy metal wastes, or inorganic wastes.

Technology Performance

This technology was tested in a SITE demonstration project at EPA's Combustion Research Facility using a mixture of 40 percent contaminated soil from a Superfund site and 60 percent decanter tank tar sludge from coking operations. Six polynuclear aromatic hydrocarbon compounds were selected as the principal organic hazardous constituents (POHC) for the test program: naphthalene, acetaphthylene, fluorene, phenanthrene, anthracene, and fluoranthene.

The Pyretron® technology achieved greater than 99.99 percent destruction and removal efficiencies (DRE) of all POHCs measured in all test runs performed. Several promising results were observed in the demonstration:

- The Pyretron® technology, with oxygen enhancement, achieved double the waste throughput possible with conventional incineration;
- All particulate emission levels in the scrubber system discharge were significantly below the hazardous waste incinerator performance standard of 180 mg/dscm at seven percent oxygen;
- Solid residues were contaminant-free;
- There were no significant differences in transient carbon monoxide level emissions between air-only incineration and Pyretron® oxygen enhanced operation; and
- Costs savings were able to be achieved in many situations.

Field evaluations were conducted under the SITE Demonstration Program, yielding several conclusions:

- The Pyretron® burner system is a viable technology for treating Superfund wastes;
- The system is capable of doubling the capacity of a conventional rotary kiln incinerator. This increase is more significant for wastes with low heating values;
- In situations where particulate carryover causes operational problems, the Pyretron® system may increase reliability; and
- The technology can be an economical addition to an incinerator when operating and fuel costs are high, and oxygen costs are relatively low.

EPA has published both the Technology Evaluation Report and Application Analysis Report for this technology.

Remediation Costs

The capital costs for the Pyretron® system used in the SITE demonstration was $150,000. In addition, $50,000 was spent in design and development work on the system.

Since this demonstration was done at a research facility and not under actual field conditions, the incremental effect that using the Pyretron® has on the cost of incinerating a ton of hazardous waste cannot be directly determined. It is likely that the major factor in determining the cost effectiveness of the Pyretron® will remain the oxygen and fuel. These costs vary widely depending upon location and scale of operation.

The two major utility costs for the demonstration were for auxiliary fuel (propane) and for oxygen. Oxygen was supplied to the program by Big Three Industries at no cost. The demonstration tests consumed about 36,800 sm^3 (1,300 MSCF) of oxygen. At typical oxygen costs, between $3,250 and $4,875 worth of oxygen was consumed over the test program.

A total of 1,760 GJ (1,670 million Btu) of propane was consumed over the demonstration test program. At typical propane costs between $5,000 and $10,000 worth of propane was consumed during the oxygen enhanced test program. About 40 percent of the propane was fired during the Pyretron® system tests. The remaining 60 percent was consumed during the conventional incineration tests.

General Site Information

EPA conducted the demonstration project at its Combustion Research Facility in Jefferson, Arkansas, using a mixture of 40 percent contaminated soil from the Stringfellow Acid Pit Superfund site in California and 60 percent decanter tank tar sludge from coking operations (RCRA listed waste K087). The demonstration began in November 1987 and was completed in January 1988.

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DEPARTMENT OF THE AIR FORCE

Radio Frequency (RF) Thermal Soil Decontamination

Solvents and Volatile and Semi-volatile Petroleum in Soils

Technology Description

The radio frequency (RF) thermal soil decontamination process removes volatile hazardous waste materials through in situ radio frequency heating of the soil and volatilization of the hazardous substances. This technology can be applied to fire training pits, spills, and sludge pits containing solvents and volatile and semi-volatile petroleum.

Radio frequency heating is performed by the application of electromagnetic energy in the radio frequency band. The energy is delivered by electrodes placed in holes drilled through the soil. The mechanism of heat generation is similar to that of a microwave oven and does not rely on the thermal properties of the soil matrix. The power source for the process is a modified radio transmitter. The exact frequency of operation is selected after evaluation of the dielectric properties of the soil matrix and the size of the area requiring treatment. The gases and vapors formed in the soil matrix can be recovered at the surface or through the electrodes used for the heating process. Condensation and collection of the concentrated vapor stream is used to capture the contaminant above ground. The system is made up of four components: (1) RF energy deposition electrode array; (2) RF power generation, transmission, monitoring, and control system; (3) vapor barrier and containment system; and (4) gas and liquid condensate handling and treatment system.

This technology has a number of advantages:

- Demonstrations have shown higher than 90 percent reduction of jet fuel components from soils;
- Contaminants are recovered in a relatively concentrated form without dilution from large volumes of air or combustion gases;
- This is an in situ method;
- All equipment is portable; and
- The soil does not have to be excavated.

Limitations of this technology include:

- High moisture or presence of ground water in the treatment zone will result in excessive power requirements to heat the soil; and
- The method cannot be used if large buried metal objects are in the treatment zone.

Technology Performance

The full-scale field demonstration at Volk Field Air National Guard Base, Camp Douglas, WI produced positive results:

- 94 to 99 percent decontamination of a 500 cubic feet block of soil was achieved during a 12-day period. 97 percent of semivolatile hydrocarbons and 99 percent of volatile aromatics and aliphatics were removed;
- Contaminant removal at the 2 meter depth, the fringe of the heated zone, exceeded 95 percent;
- The 70-76 percent contaminant reduction in the immediate area outside the heated zone indicates that there was no net migration of contaminant from the heated area to the surrounding soil; and
- Results show that substantial removal of high boiling contaminants can be achieved at temperatures significantly lower than their boiling point. This occurs due to the long residence time provided at lower temperatures and steam distillation provided by the native moisture.

Remediation Costs

It is estimated that the treatment cost will vary between $28 to $60 per ton of soil. Based upon the bench-scale tests, it is estimated that the treatment of a 3-acre site to a depth of 8 feet containing 12 percent moisture raised to a temperature of 170 degrees Celsius would cost $42 per ton. The treatment of such a site would require about one year. The initial capital equipment investment for full-scale projects is estimated to be about $1.5 million. Power requirements are approximately 500 kwhr per cubic yard to reach a temperature of 150 degrees Celsius.

General Site Information

A bench-scale pilot test (volume < 20 drums) has been conducted at ITT Research Institute facilities. A full-scale demonstration was completed at Volk Field (ANGB), WI during October 1989. Full-scale implementation began during the Fall of 1990 at Kelly AFB, San Antonio, Texas.

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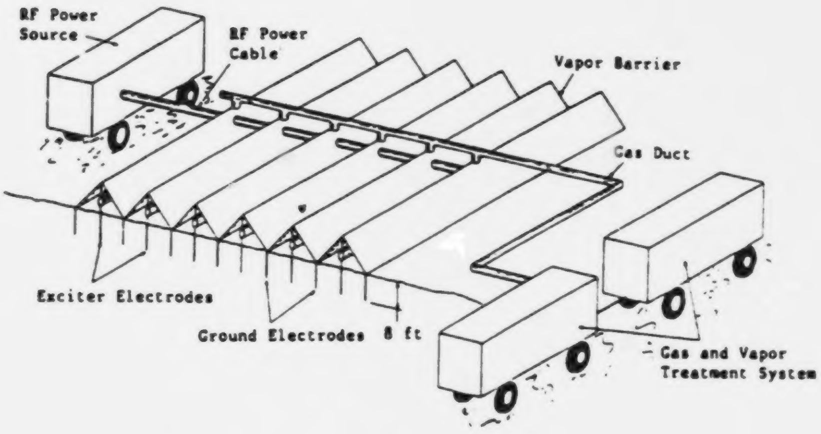
RF Power Source
RF Power Cable
Vapor Barrier
Gas Duct
Exciter Electrodes
Ground Electrodes
8 ft
Gas and Vapor Treatment System

Waste-to-Fuel Recycling

Petroleum Hydrocarbons in Sludges

Technology Description

This thermal treatment process is a mobile, low-temperature, recycling process that produces solid fossil fuel from otherwise hazardous, oily petroleum sludges. A thick, sticky tar or waste is converted into a light, organic liquid and a solid cake, that can be more easily handled. A screw flight dryer (auger) dries the petroleum sludges, resulting in a fossil fuel product. Other by-products include a light hydrocarbon liquid and water. These by-products condense from vapors emitted during the heating stages of the process. Hydrocarbons are recycled and the water is treated before release.

This process is applicable to petroleum sludges. The sludge must not have a low pH and must be dewatered to a maximum of 50 to 60 percent moisture. The sludge must be screened to prevent large debris from entering the dryer.

Technology Performance

Pilot scale tests have been conducted on hazardous petroleum refinery sludges. This technology was accepted into the SITE Demonstration Program in June 1990.

Remediation Costs

Cost information is not available.

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X*TRAX^{TM} Low-Temperature Thermal Desorption

Organics in Soil

Technology Description

The X*TRAX^{TM} technology is a low-temperature (200 to 900° F) thermal separation process designed to remove organic contaminants from soils, sludges, and other solid media. It is not an incinerator or a pyrolysis system. Chemical oxidation and reactions are not encouraged, and no combustion byproducts are formed. The organic contaminants are removed as a condensed high BTU liquid, which must then be either destroyed in a permitted incinerator or used as a supplemental fuel. Because of lower operating temperatures and gas flow rates, this process is less expensive than incineration.

An externally-fired rotary dryer is used to volatilize the water and organic contaminants into an inert carrier gas stream. The processed solids are then cooled with condensed water. The moisture content is adjusted to eliminate dusting and produce a solid that is ready to be placed and compacted in its original location. The feed rate, the dryer temperature, and the residence time of materials in the dryer can be adjusted to control the degree of contaminant removal.

The organic contaminants and water vapor driven from the solid are transported out of the dryer by an inert nitrogen carrier gas. The carrier gas flows through a duct to the gas treatment system, where organic vapors, water vapors, and dust particles are removed and recovered from the gas. The gas first passes through a high-energy scrubber. Dust particles and 10 to 30 percent of the organic contaminants are removed by the scrubber. The gas then passes through two heat exchangers in series, where it is cooled to less than 40°F. Most of the remaining organic and water vapors are condensed as liquids in the heat exchangers.

The majority of the carrier gas passing through the gas treatment system is reheated and recycled to the dryer. Approximately 5 to 10 percent of the gas is cleaned by passing it through a filter and two carbon adsorbers, before it is discharged to the atmosphere. The volume of gas released from this process vent is approximately 100 to 200 times less than an equivalent capacity incinerator. This discharge helps maintain a small negative pressure within the system and prevents potentially contaminated gases from leaking. The discharge also allows makeup nitrogen to be added to the system, preventing oxygen concentrations from exceeding combustibility limits.

Technology Performance

Chem-Waste Management currently has three X*TRAX systems available: laboratory, pilot, and full-scale. There are two laboratory-scale systems being used for treatability studies. One system is operated by Chem Nuclear systems, Inc. in Barnwell, SC for mixed (RCRA/Radioactive) wastes; and the other by CWM RD&D at its facility in Geneva, IL, for RCRA and Toxic Substances and Control Act (TSCA) wastes. More than 30 tests have been completed since January 1988. Results from these laboratory-scale tests included 97.9 percent removal efficiency for soil contaminated with 805 ppm polychlorinated biphenyls (PCBs).

The pilot-scale system is in operation at the CWM Kettleman Hills facility in California. During 1989-90, ten different PCB- contaminated soils were processed under a TSCA RD&D permit which expired in January 1990. For soils containing 120 to 6,000 ppm PCBs, the removal efficiency ranged from 97.2 to 99.5%. Nine of the ten soils were reduced to less than 25 ppm.

The first Model 200 full-scale X*TRAX system was completed in early 1990. The system will be used to remediate 35,000 tons of PCB-contaminated soil. EPA plans to conduct a SITE demonstration during this remediation.

This technology was developed primarily for on-site remediation of organic contaminated soils. The process can remove and collect volatiles, semivolatiles, and PCBs, and has been demonstrated on a variety of soils ranging from sand to very cohesive clays. Filter cakes and pond sludges have also been successfully processed. In most cases, volatile organics are reduced to below 1 ppm and frequently to below the laboratory detection level. Semivolatile organics are typically reduced to less than 10 ppm and frequently below 1 ppm. Soils containing 120 to 6,000 ppm PCBs have been reduced to 2 to 25 ppm.

This process is not applicable to heavy metals, with the exception of mercury. However, stabilization agents can be added to the feed or treated solids before cooling for metals treatment. Tars and heavy pitches create material handling problems.

Remediation Costs

Cost information is not available.

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Vapor Extraction

DEPARTMENT OF THE NAVY
UNITED STATES OF AMERICA

Ground-Water Vapor Recovery System

Volatile Organic Compounds in Ground Water

Technology Description

In this treatment, injection and extraction wells are placed outside and inside of an area of contamination. Positive pressure, from either water or air, is placed on the injections wells. Water is pumped from the extraction wells to a thermal aeration system to drive off the contaminants. Resulting vapors go to an internal combustion engine. If enough free product is available in the ground water during the cleanup process, waste hydrocarbons could be used to power the engine without the need for additional fuel.

Technology Performance

Full-scale implementation of this system is scheduled in 1991 at the Seal Beach Navy Weapons Station. This method is applicable for volatile fuels or other volatile organic compounds. This treatment requires that the contaminant be combustible. Air permits are required in some areas.

Remediation Costs

The capitol cost for purchasing and installing the engine and wells is between $70,000 and $100,000.

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In Situ Air Stripping with Horizontal Wells

TCE and PCE in Soil and Ground Water

Technology Description

In situ air stripping using horizontal wells is designed to concurrently remediate unsaturate-zone soils and ground water containing volatile organic compounds (VOCs). The in situ air stripping concept utilizes two parallel horizontal wells: one below the water table and one in the unsaturated (vadose) zone. A diagram of the technology has been provided. The deeper well is used as a delivery system for the air injection. VOCs are stripped from the ground water into the injected vapor phase and are removed from the subsurface by drawing a vacuum on the shallower well in the vadose zone. The technology is based on Henry's Law, and the affinity of VOCs for the vapor phase. The technology is probably most effective in soils with high permeability and likely works best in sandier units with no significant aquitards between the injection and extraction wells. Horizontal wells are utilized because they provide more surface area for injection of reactants and extraction of contaminants and they have great utility for subsurface access under existing facilities.

First, a vacuum was drawn on the shallow well for a period of two weeks. Concentration and temperature of the extracted vapors were measured at least three times a day. Air injection was then added at three different rates and at two different temperatures. Each of the operating regimes was operated for a minimum of two weeks. Helium tracer tests were also conducted to learn more about vapor flow paths and the heterogeneity of the system between the two wells. To assist with analysis and monitoring of the demonstration, tubes of varying lengths were installed in both horizontal wells to monitor pressure and concentrations along their entire length.

Technology Performance

Almost 16,000 pounds of solvents were removed during the test at the U.S. Department of Energy's (DOE) Savannah River Site (SRS). Extraction rates during the vapor extraction phase averaged 110 pounds of VOCs per day. The extraction flow rate was constant at approximately 580 scfm during the entire length of the test. During the air injection periods with medium (170 scfm) and high (270 scfm) rates, approximately 130 pounds of VOCs were removed daily.

Concentrations of chlorinated solvents removed during vapor extraction only decreased rapidly during the first two days of operation. Initial concentrations were as high as 5,000 ppm but stabilized at 200 to 300 ppm. Concentrations of VOCs in the ground water were significantly reduced in several of the monitoring wells. For example, ground water from two monitoring wells showed changes from 1600 and 1800 ug/L TCE at the beginning of the test to 10 to 30 ug/L at the end of the 20-weeks. However, ground water in several of the wells showed no significant change and ground water in three wells actually had trichlorethylene (TCE) concentrations increase. One possible explanation for this was that more contaminated water at depth (below the monitoring point) was being forced upward due to air injection.

The activity of indigenous microorganisms was found to increase at least an order of magnitude during the air injection periods. This activity then decreased when the air injection was terminated. It is possible that simple injection of air stimulated microorganisms that have the potential to degrade TCE. Injection of heated air appeared to have no effect on the amount of contaminant extracted from the shallow well.

Remediation Costs

The cost of the remediation project, not including site characterization was approximately $300,000, or $20/pound of contaminant removal. Site preparation costs, including well installation were $300,000 to $450,000. Equipment for this demonstration test was rented, however purchase of the vacuum blower and compressor would be in the range of $200,000.

General Site Information

This 20-week field demonstration project was conducted at the U.S. Department of Energy's (DOE) Savannah River Site (SRS) in Aiken, South Carolina, between July and December, 1990. Trichloroethylene (TCE) and tetrachloroethylene (PCE) were used at SRS as metal degreasing solvents for a number of years. The in situ test was conducted at the SRS Integrated Demonstration Site in the M-Area, along an abandoned process sewer line that carried wastes to a seepage basin which was operated between 1958 and 1985. A ground-water plume containing elevated levels of these compounds exists over an area greater than one square mile. The sewer line acted as a source of VOCs as it is known to have leaked at numerous locations along its length. Because the source of contamination was linear at this particular location within the overall plume, horizontal wells were selected as the injection/extraction system.

The Savannah River Site is located on the upper Atlantic Coastal Plain. The site is underlain by a thick wedge of unconsolidated Tertiary and Cretaceous sediments that overlay the basement, which consists of preCambrian and Paleozoic metamorphic rocks and consolidated Triassic sediments. Ground-water flow at the site is controlled by hydrologic boundaries: flow at and immediately below the water table is to local tributaries; and flow in the lower aquifer is to the Savannah River or one of its major tributaries. The water table is located at approximately 135 feet. Ground water in the vicinity of the process sewer line contains elevated concentrations of TCE and PCE to depths of greater than 180 feet.

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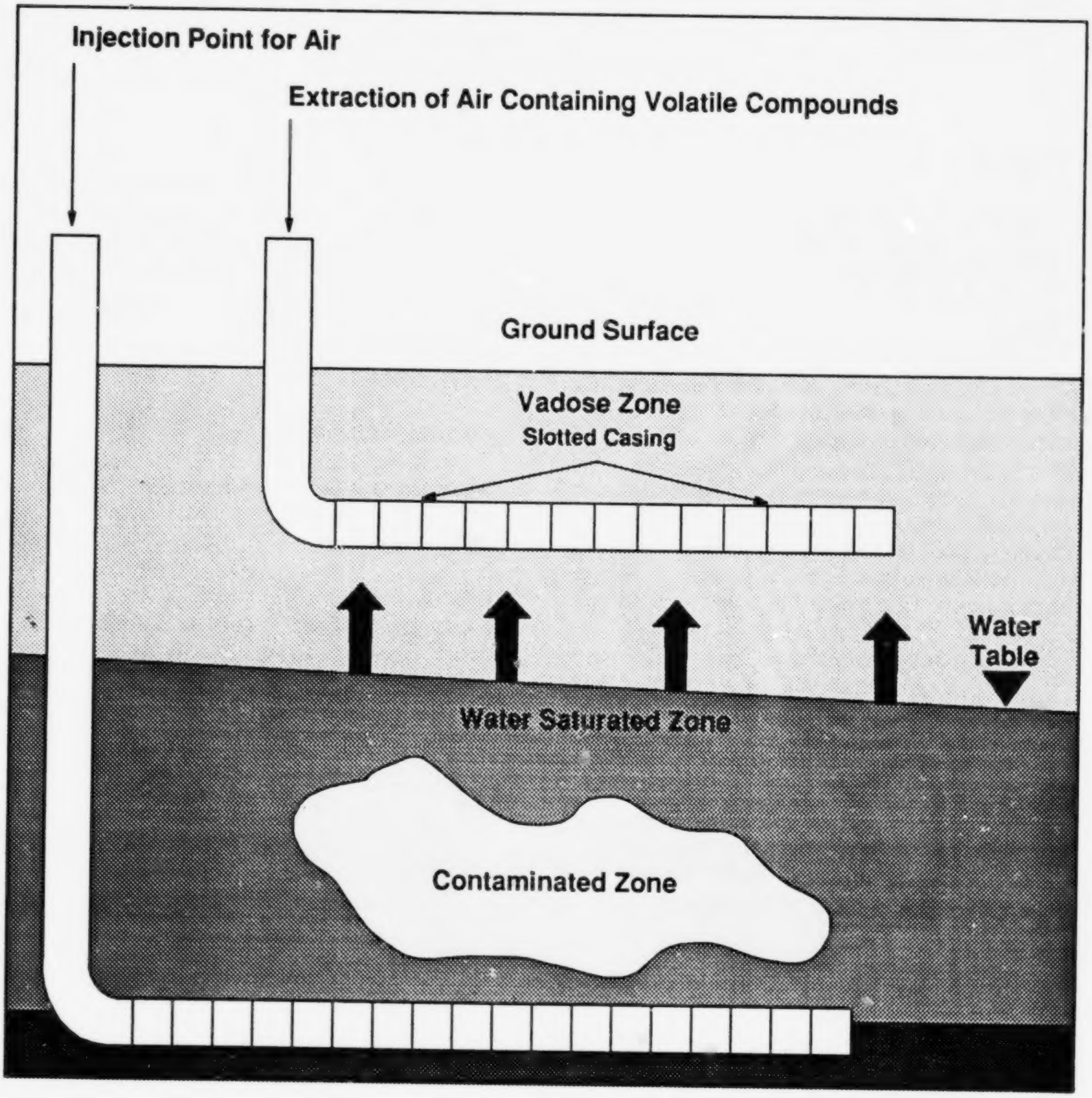
Injection Point for Air
Extraction of Air Containing Volatile Compounds
Ground Surface
Vadose Zone
Slotted Casing
Water Table
Water Saturated Zone
Contaminated Zone

f13120-1

DEPARTMENT OF THE AIR FORCE
UNITED STATES OF AMERICA
MCMXLVII

In Situ Soil Venting

Fuels and Trichloroethylene in Unsaturated Soils

Technology Description

The in situ soil venting process removes volatile contaminants such as fuels and trichloroethylene from unsaturated soils. This technology can be applied to fire training pits, spills and the unsaturated zone beneath leach pits. The method is most applicable for contamination at depths greater than 40 feet in fairly permeable soils.

Venting wells are placed in the unsaturated zone and connected to a manifold and blower. A vacuum is applied to the manifold, and gases are extracted from the soil and fed to the treatment system. The air flow sweeps out the soil gas, disrupting the equilibrium existing between the contaminant adsorbed on the soil and its vapor phase. This results in further volatilization of the contaminant on the soil and subsequent removal in the air stream. Depending upon the individual site and the depth of the contaminated zone, it might be necessary to seal the surface to the throughput of air.

This technology has a number of advantages. Specifically, it is inexpensive, especially if the emissions require no treatment. The equipment is easily emplaced. It is less expensive than excavation at depths greater than forty feet, and the costs are similar for depths between 10 and 40 feet. Operation is simple, excavation of contaminated soil is not required, and the site is not destroyed.

Despite the advantages of this technology, limitations do exist. This process is a transfer-of-media method - the waste is not destroyed. At depths of less than 10 feet, excavation could be less expensive, depending upon the type of waste treatment required. The contamination must be located in the unsaturated zone above the nearest aquifer. Prior bench-scale testing is important in determining the effectiveness of the method to a specific site. To date, few field data exist on the level of cleanup. If the contamination includes toxic volatile organic carbons, then treatment of the vented gases may be required. The level of treatment is based upon local requirements.

Technology Performance

Analysis of the technology demonstration at Hill Air Force Base (AFB) have shown the following results:

- Soil gas venting may provide oxygen for biodegradation;
- Based on data from extracted gases, 80 percent of a 100,000-liter fuel spill was removed in 9 months of operation;
- Soil analysis following a full-scale in situ field test indicated an average fuel residual of less than 100 ppm in the soils;
- At initial air flow rates of 250 cubic feet per minute, the full-scale system was removing 50 gallons per day of JP-4 from the soil. The venting rates were then increased to over 1,000 cubic feet per minute. After ten months of venting, over 100,000 pounds of JP-4 had been removed. Hill AFB continues to operate the system at a reduced flow rate to enhance the in situ biodegradation of remaining hydrocarbons; and
- Approximately 20-25 percent of the reduction in fuel hydrocarbons was caused by biodegradation.

Remediation Costs

The costs range from $15 per ton of contaminated soil, excluding emission treatment, up to approximately $85 per ton using activated carbon emission treatment. Estimated costs of this technology for sandy soils is $10 a cubic yard. Catalytic incineration of VOCs can double this cost. However, at Hill AFB, catalytic incineration only cost $10 per cubic yard.

General Site Information

Operation of a full-scale in situ soil-venting system at a 27,000-gallon JP-4 spill at Hill AFB began in December 1988. A full-scale in situ field test was completed in October 1989 at Hill AFB, Utah.

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In Situ Soil Venting

Volatile Contaminants in Unsaturated Soil

Technology Description

This in situ soil venting process removes volatile contaminants from unsaturated soils. This technology can be applied to fire training pits, spills, and the unsaturated zone beneath leach pits. The method is most applicable for contamination at depths greater than 40 feet in fairly permeable soils.

Venting wells are placed in the unsaturated zone and connected to a manifold and blower. A vacuum is applied to the manifold, and gases are extracted from the soil and fed to the treatment system. Depending upon the individual site and depth of the contaminated zone, it might be necessary to seal the surface to prevent channeling. Air injection wells can be used to increase the throughput of air.

Technology Performance

Pilot-scale testing at the Twin Cities Army Ammunition Plant (TCAAP) has removed 70 tons of contaminants from the soil in one area, but the absolute extent of cleanup has not yet been determined. This method is considered most applicable for contamination at depths greater than 40 feet in fairly permeable soils.

Remediation Costs

The costs for in situ soil venting can be as low as $15 per ton of contaminated soil, excluding emission treatment. If carbon adsorption treatment is used, the costs could be around $85 per ton. Based upon the pilot study at TCAAP, the cost to treat a site contaminated to a depth of 20 feet was between $15 and $20 per cubic yard, including carbon adsorption treatment of the contaminated air and soil sampling.

General Site Information

This method has been implemented by the Army at the Twin Cities Army Ammunition Plant (TCAAP) in Minnesota.

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In Situ Steam/Air Stripping Process

VOCs in Soil

Technology Description

The two main components of the Toxic Treatments (USA) Inc. in situ steam/air stripping process are the process tower and process train. The process tower contains two counter-rotating hollow-stem drills, each with a modified cutting bit five feet in diameter, capable of operating to a 27-foot depth. Each drill contains two concentric pipes. The inner pipe is used to convey steam to the rotating cutting blades. The steam is supplied by an oil-fired boiler at 450°F and 450 psig. The outer pipe conveys air at approximately 300°F and 250 psig to the rotating blades.

Steam is piped to the top of the drills and injected through the cutting blades. The steam heats the ground being remediated, increasing the vapor pressure of the volatile contaminants and thereby increasing the rate at which they can be stripped. Both the air and steam serve as carriers to convey these contaminants to the surface. A metal box, called a shroud, seals the process area above the rotating cutter blades from the outside environment, collects the volatile contaminants, and ducts them to the process train.

In the process train, the volatile contaminants and the water vapor are removed from the off-gas stream by condensation. The condensed water is separated from the contaminants by distillation, then filtered through activated carbon beds and subsequently used as make-up water for a wet cooling tower. Steam is also used to regenerate the activated carbon beds and as the heat source for distilling the volatile contaminants from the condensed liquid stream. The recovered concentrated organic liquid can be recycled or used as a fuel in an incinerator.

This technology is applicable to organic contaminants, such as hydrocarbons and solvents with sufficient vapor pressure in the soil. The technology is not limited by soil particle size, initial porosity, chemical concentration, or viscosity.

Technology Performance

The SITE demonstration of the technology at the Annex Terminal in San Pedro, California exhibited promising results:

- Greater than 85 percent of the volatile organic compounds (VOCs) in the soil were removed;
- As much as 55 percent of semivolatile organic compounds (SVOCs) in the soil were removed;
- Fugitive air emissions from the process were very low; and
- No downward migration of contaminants occurred due to the soil treatment.

Remediation Costs

Cost information is not available.

General Site Information

A SITE demonstration was performed the week of September 18, 1989 at the Annex Terminal, San Pedro, California. Twelve soil blocks were treated for VOCs and SVOCs. EPA collected various liquid samples and closely monitored and recorded operating procedures. During the demonstration EPA collected and analyzed post-treatment soil samples of EPA 8240 and 8270 chemicals. In January 1990, six blocks, which had been previously treated in the saturated zone, were analyzed for EPA 8240 and 8270 chemicals. Currently, the Technology Evaluation Report has obtained EPA clearance for publication. The Application Analysis Report is being prepared.

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Integrated Vapor Extraction and Steam Vacuum Stripping

VOCs in Ground Water and Soil

Technology Description

The integrated AquaDetox/SVE system simultaneously treats ground water and soil contaminated with volatile organic compounds (VOCs). The integrated system consists of two basic processes: an AquaDetox moderate vacuum stripping tower that uses low-pressure steam to treat contaminated ground water, and a soil gas vapor extraction/reinjection (SVE) process to treat contaminated soil. The two processes form a closed-loop system that provides simultaneous in situ remediation of contaminated ground water and soil with no air emissions.

This technology is suitable for removing VOCs, including chlorinated hydrocarbons, in ground water and soil. AquaDetox is capable of effectively removing over 90 of the 110 volatile compounds listed in 40 CFR Part 261, Appendix VIII.

AquaDetox is a high efficiency, countercurrent stripping technology developed by Dow Chemical Company. A single-stage unit will typically reduce up to 99.99 percent of VOCs from water. The SVE system uses a vacuum to treat a VOC-contaminated soil mass, inducing a flow of air through the soil and removing vapor phase VOCs with the extracted soil gas. The soil gas is then treated by carbon beds to remove additional VOCs and reinjected into the ground. The AquaDetox and SVE system share a granulated activated carbon (GAC) unit. Noncondensable vapor from the AquaDetox system is combined with the vapor from the SVE compressor and decontaminated by the GAC unit. By-products of the system are a free-phase recyclable product and treated water. Mineral regenerable carbon will require disposal after approximately three years.

A key component of the closed-loop system is a vent header unit designed to collect the noncondensable gases extracted from the ground water or air that may leak into the portion of the process operating below atmospheric pressure. Furthermore, the steam used to regenerate the carbon beds is condensed and treated in the AquaDetox system.

Technology Performance

This system is currently being used at an aeronautical systems facility in Burbank, California, to treat ground water contaminated with as much as 2,200 ppb of TCE and 11,000 ppb PCE, and soil gas with a total VOC concentration of 6,000 ppm. Contaminated ground water is being treated at a rate of up to 1,200 gpm while soil gas is removed and treated at a rate of 300 cfm. The system occupies approximately 4,000 square feet.

This technology was also tested in a SITE demonstration in September 1990. EPA is currently preparing demonstration results and expects to make these results available in early 1991.

Remediation Costs

Cost information is not available.

General Site Information

The AWD AquaDetox/SVE system is currently being used at the Lockheed Aeronautical Systems Company in Burbank, California. In addition, EPA conducted a SITE demonstration of the technology in September 1990 as part of an ongoing remediation effort at the San Fernando Valley Ground-Water Basin Superfund site in Burbank, California.

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Terra Vac In Situ Vacuum Extraction
VOCs in Soils

Technology Description

The Terra Vac in situ vacuum extraction technology can be used to remove and treat volatile organic compounds (VOCs) from the vadose or unsaturated zone of soils. This technology is applicable to organic compounds that are volatile or semivolatile at ambient temperatures in soils and ground water. Often, these compounds can be removed from the vadose zone before they contaminate ground water. Contaminants must have a Henry's constant of 0.001 or higher for effective removal.

During the in situ vacuum extraction process, a well is used to extract soil gas containing organic contaminants like trichloroethylene (TCE). The extracted contaminant stream passes through a vapor/liquid separator, and the resulting off-gases undergo treatment, before being released into the atmosphere. Removing VOCs from the vadose zone using a vacuum is a patented process.

The technology does not require soil excavation and is not limited by depth. The technology works best at sites that are contaminated by liquids with high vapor pressures. The success of the system depends on site conditions, soil properties, and the chemical properties of the contaminants. The process works in soils of low permeability (clays) if the soil has sufficient air-filled porosity. Depending on the soil type and the depth to ground water, the radius of influence of a single extraction well can range from tens to hundreds of feet.

The technology uses readily available equipment such as extraction and monitoring wells, manifold piping, a vapor/liquid separator, a vacuum pump, and an emission control device, such as an activated carbon canister. Once a contaminated area is completely defined, an extraction well is installed and connected by piping to a vapor/liquid separator device. A vacuum pump draws the subsurface contaminants through the well, to the separator device, and through a treatment system consisting of activated carbon or a catalytic oxidizer before the air stream is discharged to the atmosphere. Subsurface vacuum and soil vapor concentrations are monitored using vadose zone monitoring wells.

Typical contaminant recovery rates range between 20 and 2,500 pounds per day, and are a function of the degree of contamination at the site. Typically, the more volatile the organic compound, the faster the process works. The process is cost-effective at sites where contaminated soils are predominantly above or below the water table; dual vacuum extraction systems have been designed for both vapor and ground-water recovery.

Technology Performance

An in situ vacuum extraction demonstration at the Groveland Wells Superfund site used four extraction wells to pump contaminants to the process system. Four monitoring wells were used to measure the impact of treatment on site contamination. During the SITE demonstration, 1,300 pounds of volatile organics, mainly TCE, were extracted during a 56-day operational period. The volatiles were removed from both highly permeable strata and low permeability clays. The process achieved nondetectable levels of VOCs in the soil at some locations at the test area. The VOC concentration in soil gas was reduced 95 percent.

The Terra Vac system was also tested at several other Superfund and non-Superfund sites. These field evaluations yielded several conclusions:

- The process represents a viable technology to fully remediate a site contaminated with volatile organic compounds. Cleanup to non-detectable levels in soil can be achieved under certain conditions;

- The two major considerations in applying this technology are the volatility of the contaminants (i.e., Henry's constant) and the site soil porosity;
- The process performed well in removing volatile organic compounds from soil with measured permeabilities of 10^{-4} to 10^{-8} cm/sec;
- Pilot demonstrations are necessary at sites with complex geology or contaminant distributions; and

Remediation Costs

Based on available data, treatment costs are typically $40 per ton of contaminated soil, but can range between $10 and $150 per ton depending upon requirements for off-gas or wastewater treatment.

General Site Information

EPA first applied this technology at a Superfund site in Puerto Rico, where carbon tetrachloride had leaked from an underground storage tank. In situ vacuum extraction processes have been used at more than 100 waste sites across the United States, such as the Verona Wells Superfund Site in Battle Creek, Michigan, which contains trichloroethylene and contaminants from solvent storage and spills. The SITE Program performed a field demonstration of the process at the Groveland Wells Superfund site in Groveland, Massachusetts, which was contaminated with TCE. EPA published the Technology Evaluation Report and Applications Analysis Report.

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Vacuum-Induced Soil Venting

Gasoline in Unsaturated Soil

Technology Description

The vacuum-induced venting process provides in situ cleanup of gasoline contamination above and below the water table. It reduces contamination to levels low enough to eliminate further leaching or desorption of gasoline into the ground water. This technology can be applied to hydrocarbon fuels in unsaturated soil.

A vapor/ground-water extraction well, and a well for monitoring the vacuum induced venting were installed in the gas spill area. The vapor extraction/monitor wells each have five individually screened intervals in the unsaturated zone and two screened intervals below the water table. A vacuum-extraction system with thermal oxidizer is installed using one well to remediate the spill area. The vacuum-extraction system operates with a vacuum of between 20-25 inches of mercury and with a flow rate of approximately 60 cfm. The present system uses an open pipe at the top of an air-driven pump, which is manually adjusted to follow the gasoline water interface. Both wells are used for skimming gasoline.

Technology Performance

Results from testing the vacuum-induced soil venting technology at the Department of Energy's (DOE) Lawrence Livermore National Laboratory (LLNL) are positive:

- Approximately 100 gallons of free product have been removed with this system;
- Approximately 5000 gallons of gasoline have been removed through vacuum-induced venting through the calendar year 1989;
- Over the calendar year 1989, total fuel hydrocarbon concentrations (measured at the inlet of the thermal oxidizer), have decreased from 16,000 ppm in January 1989 to about 3,000-4,000 ppm at year end; and
- The thermal oxidizer that destroys the gaseous hydrocarbons as they are removed has operated with a 99.8 percent destruction efficiency.

Remediation Costs

Cost information is not available.

General Site Information

Prior to 1979, approximately 17,000 gallons of regular gasoline leaked into the soil and ground water from an underground fuel storage tank at the DOE's Lawrence Livermore National Laboratory. Vacuum-induced venting was demonstrated at this site as a method to clean the gasoline contamination in situ.

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Soil Washing

BEST Solvent Extraction

Hydrocarbons and Other Organic Containments in Soils and Sludges

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Technology Description

This BEST process is a mobile solvent extraction system that uses one or more secondary or tertiary amines, usually triethylamine (TEA), to separate hydrocarbons from soils and sludges. This technology is applicable for most organics or oily contaminants in sludges or soils, including polychlorinated biphenyls (PCBs) (see Table 1).

Solvent extraction is potentially effective in treating the contaminants by separating the sludges into three fractions: oil, water, and solids. As the fractions separate, contaminants are partitioned into specific phases. For example, PCBs are concentrated in the oil fraction, while metals are separated into the solids fraction. The overall volume and toxicity of the original waste solids are thereby reduced and the concentrated waste streams can be efficiently treated for disposal.

The BEST technology is based on the fact that TEA is completely soluble in water at temperatures below 20° C. Because TEA is flammable in the presence of oxygen, the treatment system must be sealed from the atmosphere and operated under a nitrogen blanket. Prior to treatment, it is necessary to raise the pH of the waste material to greater than 10, creating an environment where TEA will be effectively conserved for recycling through the process. This pH adjustment may be accomplished by adding sodium hydroxide. Pretreatment also includes screening the contaminated feed solids to remove cobbles and debris for smooth flow through the process.

The BEST process begins by mixing and agitating the cold solvent and waste in a washer/dryer. The washer/dryer is a horizontal steam-jacketed vessel with rotating paddles. Hydrocarbons and water in the waste simultaneously solvate with the cold TEA, creating a homogeneous mixture. As the solvent breaks the oil-water-solid bonds in the waste, the solids are released and allowed to settle by gravity. The solvent mixture is decanted and fine particles are removed by centrifuging. The resulting dry solids have been cleansed of hydrocarbons but contain most of the original waste's heavy metals, thus requiring further treatment prior to disposal.

The liquids from the washer/dryer vessels, containing the hydrocarbons and water extracted from the waste, are heated. As the temperature of the liquids increases, the water separates from the organics and solvent. The organics-solvent fraction is decanted and sent to a stripping column, where the solvent is recycled and the organics are discharged for recycling or disposal. The water phase is passed to a second stripping column, where residual solvent is recovered for recycling. The water is typically discharged to a local wastewater treatment plant.

Technology Performance

The BEST technology is modular, allowing for on-site treatment. Performance of the BEST solvent extraction process can be influenced by the presence of detergents and emulsifiers, low pH materials and reactivity of the organics with the solvent. Based on the results of many bench-scale treatability tests conducted at the General Refining Superfund site, the process significantly reduces the hydrocarbon concentration in the solids.

Other advantages of the technology include the production of dry solids, the recovery and reuse of soil, and waste volume reduction. By removing organic contaminants, the process reduces the overall toxicity of the solids and water streams. It also concentrates the contaminants into a smaller volume, allowing for efficient final treatment and disposal.

Remediation Costs

Cost information is not available.

General Site Information

The first full-scale BEST unit was used at the General Refining Superfund site in Garden City, Georgia. This solvent extraction technology is the selected remedial action at the Pinnete's Salvage site in Maine and is the preferred alternative at the F. O'Connor site in Maine. The demonstration of the BEST process under the SITE Program is pending selection of an appropriate site.

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TABLE 1
SPECIFIC WASTES CAPABLE OF TREATMENT USING SOLVENT EXTRACTION

RCRA Listed Hazardous Wastes

- Creosote-Saturated Sludge
- Dissolved Air Flotation (DAF) Float
- Slop Oil Emulsion Solids
- Heat Exchanger Bundle Cleaning Sludge
- API Separator Sludge
- Tank Bottoms (Leaded)

Non-Listed Hazardous Wastes

- Primary Oil/Solids/Water Separation Sludges
- Secondary Oil/Solids/Water Separation Sludges
- Bio-Sludges
- Cooling Tower Sludges
- HF Alkylation Sludges
- Waste FCC Catalyst
- Spent Catalyst
- Stretford Unit Solution
- Tank Bottoms
- Treated Clays

Biogenesis Soil Cleaning Process

Hydrocarbons in Soil

Technology Description

The BioGenesis^{TM} process uses a specialized truck, gravity and cyclone separators, and a bioreactor to wash hydrocarbon-contaminated soil. The wash rate for hydrocarbon contamination up to 5,000 ppm is 25 tons per hour; higher contamination levels require slower wash rates. After the first wash, 100 to 200 ppm of the residuals remain. A second wash reduces residuals even further. A single wash removes 95 to 99 percent of hydrocarbon concentrations up to 16,000 ppm. One or two additional washes are used for concentrations up to 45,000 ppm.

The residuals biodegrade at an accelerated rate due to contact with BioVersal^{TM}, a light, alkaline, organic formula used to reduce oil contamination. Twenty-five tons of contaminated soil are dumped into a mixture of water and BioVersal^{TM}. For 15 to 30 minutes, aeration equipment agitates the mixture, washing the soil and encapsulating oil molecules with BioVersal^{TM}.

After washing, the liquid products are recycled or treated, and the soil is dumped out of the soil washer. The bioreactor processes the minimal amount of wastewater produced by the soil washer. Recovered oils are recycled. PCBs, metals, and other hazardous materials are extracted in the same manner, then processed using specific treatment methods. All equipment is mobile, and treatment is normally on-site.

Technology Performance

This technology is used commercially in Europe. It is applicable to soil contaminated with volatile and nonvolatile hydrocarbons. These include asphaltenes, polychlorinated biphenyls (PCBs), polycylic hydrocarbons, and epichlorhydrin.

This technology was accepted into the SITE Program in July 1990.

Remediation Costs

Cost information is not available.

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Biotrol Soil Washing System

Wood Preserving Wastes, Petroleum Hydrocarbons, Pesticides, PCBs, Industrial Chemicals, and Metals in Soil

Technology Description

The Biotrol Soil Washing System is a patented, water-based, volume reduction process for treating excavated soil contaminated with wood preserving wastes, petroleum hydrocarbons, pesticides, polychlorinated biphenyls (PCBs), various industrial chemicals, and metals. This soil washing technology may be used to treat fine grained soils (silt, clay, and soil organic matter) and coarse grained soils (sand and gravel). The objective of the process is to concentrate the contaminants in a smaller volume of material separate from a washed soil product, with the goal that this soil product meet appropriate cleanup standards.

After debris is removed, soil is mixed with water and subjected to various unit operations common to the mineral processing industry. Process steps can include mixing trommels, pug mills, vibrating screens, froth flotation cells, attrition scrubbing machines, hydrocyclones, screw classifiers, and various dewatering operations. The core of the process is a multi-stage, counter-current, intensive scrubbing circuit with interstage classification. The scrubbing action disintegrates soil aggregates, freeing contaminated fine particles from the coarser sand and gravel. In addition, surficial contamination is removed from the coarse fraction by the abrasive scouring action of the particles themselves. Contaminants may also be solubilized as dictated by solubility characteristics or partition coefficients.

The efficiency of soil washing can be improved using surfactants, detergents, chelating agents, pH adjustment, or heat. In many cases, however, water alone is insufficient to achieve the desired level of contaminant removal while minimizing cost. The volume of material requiring additional treatment or disposal is reduced significantly by separating the washed, coarser soil components from the process water and contaminated fine particles. The contaminated residual products can be treated by other methods. Process water is normally recycled after biological or physical treatment. Options for the contaminated fines can include off-site disposal, incineration, stabilization, or biological treatment.

This technology was initially developed to clean soils contaminated with wood preserving wastes such as polyaromatic hydrocarbons (PAHs) and pentachlorophenol (PCP). However, the technology is also applicable to soils contaminated with petroleum hydrocarbons, pesticides, polychlorinated biphenyls (PCBs), various industrial chemicals, and metals.

Technology Performance

During the SITE demonstration of this technology at the MacGillis & Gibbs Superfund site, a pilot-scale unit with a treatment capacity of 500 pounds per hour was operated 24 hours per day during the demonstration. Feed for the first phase of the demonstration (two days) consisted of soil contaminated with 170 ppm PCP and 240 ppm total PAHS. During the second phase (seven days), soil containing 980 ppm PCP and 340 ppm total PAHs was fed to the system.

Contaminated process water from soil washing was treated biologically in a fixed film reactor and recycled. A three-stage, pilot-scale EIMCO Biolift$^{\text{TM}}$ reactor system, supplied by the EIMCO Process Equipment Company, was used to biologically treat a portion of the contaminated fines generated during soil washing.

Preliminary demonstration results showed that PCP levels in the washed soil were reduced by 91 to 93 percent. Biological treatment reduced PCP levels in the process water by 89 to 94 percent. Removal efficiencies increased as the test proceeded. Near the completion of the test, PCP removal was about 92 percent, while PAH removal ranged from 86 to 99 percent.

Remediation Costs

Cost information is not available.

General Site Information

EPA conducted the SITE demonstration of this soil washing technology from September 25 to October 27, 1989 at the MacGillis & Gibbs Superfund site in New Brighton, Minnesota. EPA expects to release the demonstration reports in the first quarter of 1991.

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Debris Washing System

Hazardous Chemicals in Solid Debris

Technology Description

EPA's Risk Reduction Engineering Laboratory (RREL) staff and PEI Associates, Inc. developed the Debris Washing System (DWS) to decontaminate debris currently found at Superfund sites throughout the country. The DWS can be applied on-site to various types of debris (metallic, masonry, or other solid debris) contaminated with hazardous chemicals such as pesticides, polychlorinated biphenyls (PCBs), lead, and other metals. EPA demonstrated the Debris Washing System under EPA's Innovative Technology Program and PEI Associates, Inc. will commercialize the technology.

The DWS consists of 300-gallon spray and wash tanks, surfactant and rinse water holding tanks, and an oil/water separator. The decontamination solution treatment system includes a diatomaceous earth filter, an activated carbon column, and an ion exchange column. The DWS unit is transported on a 48-foot semitrailer. At the treatment site, the DWS unit is assembled on a 25 by 24 foot concrete pad and enclosed in a temporary shelter.

The DWS process operates by placing a basket of debris in the spray tank with a forklift where it is sprayed with an aqueous detergent solution. An array of high pressure water jets blast contaminants and dirt from the debris. Detergent solution is continually recycled through a filter system that cleans the liquid.

The wash and rinse tanks are supplied with water at 140° F, at 60 psig. The contaminated wash solution is collected and treated prior to discharge. An integral part of the technology is treatment of the process detergent solution and rinse water to reduce the contaminant concentration to allowable discharge levels. Process water treatment consists of particulate filtration, activated carbon adsorption and ion exchange. Approximately 1,000 gallons of liquid are used during the decontamination process.

Technology Performance

During the first pilot-scale testing at the Region V Carter Industrial Superfund site, PCB reductions averaged 58 percent in batch 1 and 81 percent in batch 2. RREL and PEI then incorporated design changes and tested these changes on the unit, prior to additional field testing.

Field-testing of the upgraded pilot-scale DWS unit conducted at a Region IV Superfund site yielded promising results. PCB levels on the surfaces of metallic transformer casings were reduced to less than or equal to 10 micrograms PCB/100 cm2. All 75 contaminated transformer casings on-site were decontaminated to U.S. EPA acceptable cleanup criteria and sold to a scrap metal dealer.

The unit also was field tested at a site contaminated with Dicamba and benzonitrile. During the test, fifty-five gallon drums were cut into sections, placed in the DWS, and carried through the decontamination process. Results from this study are currently being prepared.

Remediation Costs

Cost information is not available.

General Site Information

RREL performed the first pilot-scale testing at the Region V Carter Industrial Superfund site in Detroit, Michigan. RREL field tested the unit using the upgraded pilot-scale DWS unit at a Region IV PCB-contaminated Superfund Site in Hopkinsville, Kentucky, during December 1989. RREL also field tested the unit at the Shaver's Farm site in Walker County, Georgia.

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Ghea Associates Process

Inorganic and Organic Contaminants in Soil

Technology Description

The Ghea Associates process uses selected surfactants (detergent-like chemicals) in a water solution to extract both inorganic and organic contaminants from the soil. The technology is applicable to mixtures of widely varying compositions, including organic, inorganic, volatile, and nonvolatile contaminants. The resulting mixture is purified by separating out the surfactant/contaminant complex and splitting it into a surfactant fraction, which is recovered for repeated use and a contaminants fraction.

The cleaning power of surfactants comes from the presence of both hydrophilic ("water-liking") and lipophilic ("oil-liking") groups on the same molecule. Therefore, surfactants can link an oily contaminant with the water, pulling it from its matrix the way laundry soap (a detergent) pulls soil from cloth into the wash water. Surfactants enable water to hold large quantities of oil contaminants by forming "micelles," tiny capsules of surfactant filled with the contaminant.

A variation of the process called "foam flotation," uses surfactants to form stable bubbles, which can lift heavy particles to the top of the solution. This process combines "foam flotation" with ultrafiltration to achieve complete recovery of the surfactants from the surfactant/contaminant complex and the reduction of dissolved metals.

After extraction, solids are filtered out of the washing solution. These solids are rinsed and disposed of after they are confirmed to be pure. The temperature or pH of the solution is changed so that the surfactant/contaminant separates from the water. The water is again treated and recycled through the system or discharged to the sewer. The surfactant is separated from the contaminants and also recycled. The contaminated fraction will be disposed of according to federal regulations.

This process uses the appropriate surfactant or surfactant mixtures to separate the contaminants of interest. Dosages, mixing time, and the precise means of separating the fraction of the wash water will vary with the situation.

Technology Performance

Treatability tests conducted by Ghea Associates have been promising. When tested with tar-contaminated soil, the process was able to remove more than 99 percent of the organic materials and 65 to 85 percent of some metallic contaminants from the matrix. Other treatability tests using BTX in water, trinitrotoluene in water, and gas and diesel fuel in soil have been equally successful.

Remediation Costs

Cost information is not available.

General Site Information

EPA accepted the technology into the SITE Emerging Technologies Program in July 1990. The developer is preparing the work plan and quality assurance project plan for U.S. EPA approval.

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Soil Treatment with Extraksol

Organic Contaminants in Soil

Technology Description

The Sanivan Group has developed Extraksol, a mobile solvent extraction technology which extracts organic contaminants from solids. It has been successfully tested in a number of pilot projects on a range of contaminants, including polychlorinated biphenyls (PCBs), pentachlorophenol (PCP), polyaromatic hydrocarbons (PAHs), monoaromatic hydrocarbons (MAHs), pesticides, oils, and hydrocarbons. The process extracts these contaminants from the soil by using nonchlorinated, non-persistent organic solvents, which are regenerated by distillation. The contaminants are concentrated in the distillation residues.

The three treatment steps -- soil washing, soil drying, and solvent regeneration -- occur on a flatbed trailer. The extraction fluid (solvent) is circulated through the contaminated matrix within a tumbling vat to wash the soil. Controlled temperature and pressure optimize the washing procedure. Hot inert gas dries the soil. The gas vaporizes the residual extract fluid and carries it from the tumbling vat to a condenser, where the solvent is again separated from the gas. The now solvent-free gas is reheated and reinjected into the soil as required for complete drying. After the drying cycle, the decontaminated soil may be returned to its original location.

Distillation of the contaminated solvent achieves two major objectives: (1) it minimizes the amount of solvent required to perform the extraction by regenerating it in a closed loop, and (2) it significantly reduces the volume of contaminants requiring further treatment or off-site disposal by concentrating them in the still bottoms.

The Extraksol process has several soil restrictions:

- Maximum clay fraction, 40 per cent;
- Maximum water content, 30 per cent;
- Maximum particle size if porous material, 2 inches; and
- Maximum particle size if non-porous material, 1-2 feet.

Technology Performance

This technology was accepted into the SITE program in June 1990. Plans are currently underway to demonstrate this technology at a Superfund site located in the northeastern part of Maine in late Summer 1991.

Remediation Costs

Cost information is not available.

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Solvent Extraction

Organics, Oil, and Grease in Wastewater, Soils, and Sludges

Technology Description

This technology uses liquified gas solvent to extract organics, oil, and grease from wastewater or contaminated sludges and soils. Specifically, this technology can be applied to waste containing hydrocarbons, carbon tetrachloride, chloroform, benzene, naphthalene, gasoline, vinyl acetate, furfural, butyric acid, higher organic acids, dichloroethane, oils and grease, xylene, toluene, methyl acetate, acetone, higher alcohols, butanol, propanol, phenol, heptane, polychlorinated biphenyls (PCBs) and other complex organics.

In this solvent extraction system, carbon dioxide is the gas used for aqueous solutions, while propane and/or butane is used for sediment, sludges and soils (semisolids). First, contaminated solids, slurrys or wastewaters are fed into the extractor. Solvent (gas condensed by compression) is also fed to the extractor, making nonreactive contact with the waste. Typically, more than 99 percent of the organics are separated from the feedwaste.

Following phase separation of the solvent and organics, treated water is removed from the extractor while the mixture of solvent and organics passes to the separator through a valve, where pressure is partially reduced. In the separator, the solvent is vaporized and recycled as fresh solvent. The organics are drawn off from the separator, and either reused or diposed.

The extractor design is different for contaminated wastewaters and semisolids. For wastewaters, a tray tower contactor is used, whereas for semisolids a series of extractor/decanters operating countercurrently is employed.

Technology Performance

This technology was demonstrated concurrently with dredging studies managed by the U.S. Army Corps of Engineers. The CF Systems Pit Cleanup Unit treated contaminated sediments using a liquified propane and butane mixture as the extraction solvent.

The following test results include the number of passes made during each test and the concentration of PCBs before and after each test:

Extraction efficiencies were high, despite some operating difficulties during the tests. The use of treated sediment as feed to the next pass caused cross-contamination in the system. Full scale commercial systems are designed to eliminate problems associated with the pilot plant design.

The following conclusions were drawn from this series of tests and other data:

- Extraction efficiencies of 90-98% were achieved on sediments containing between 350 and 2,575 ppm PCBs. PCB concentrations were as low as 8 ppm in the treated sediment;
- In the laboratory, extraction efficiencies of 99.9% have been obtained for volatile and semivolatile organics in aqueous and semi-solid wastes;
- Operating problems included solids being retained in the system hardware and foaming in receiving tanks. The vendor identified corrective measures that will be implemented in the full-scale commercial unit; and
- Projected costs for PCB cleanups are estimated at approximately $150 to $450 per ton, including material handling and pre- and post-treatment costs. These costs are highly sensitive to the utilization factor and job size, which may result in lower costs for large cleanups.

Remediation Costs

Cost information is not available.

General Site Information

EPA tested the pilot-scale system on PCB-laden sediments from the New Bedford (Massachusetts) Harbor Superfund site in September 1988. PCB concentrations in the harbor ranged from 300 ppm to 2,500 ppm. EPA published the Technology Evaluation Report (TER) in early 1990 (EPA/540/5-90/002).

Commercial systems have been sold to Clean Harbors in Braintree, Massachusetts, for wastewater cleanup; and to Ensco in Little Rock, Arkansas, for incinerator pretreatment. A unit is in operation at Star Enterprise in Port Arthur, Texas, treating API separator sludge to meet Best Demonstrated and Available Technology (BDAT) standards for organics.

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		PCB Concentration	
	Passes	Before	After
Test 2	9	360 ppm	8 ppm
Test 3	3	288 ppm	82 ppm
Test 4	6	2575 ppm	200 ppm

Solidification/Stabilization

Chemfix Solidification / Stabilization Process

Solid Waste in Soil and Sludge

Technology Description

This solidification/stabilization process involves an inorganic system in which soluble silicates and silicate setting agents react with polyvalent metal ions and other waste components to produce a chemically and physically stable solid material. This technology is suitable for contaminated soil, sludge, and other solid wastes. It can also be used for base, neutral, or acid extractable organics of high molecular weight, such as refinery wastes, creosote, and wood-treating wastes. Additionally, solidification/stabilization can be applied to electroplating wastes, electric arc furnace dust, and municipal sewage sludge containing heavy metals such as aluminum, antimony, arsenic, barium, beryllium, cadmium, chromium, iron, lead, manganese, mercury, nickel, selenium, silver, thallium, and zinc.

The Chemfix solidification/stabilization process operates by blending feed waste in the reaction vessel with certain reagents that are dispersed and dissolved throughout the aqueous phase. The reagents react with polyvalent ions in the waste. Inorganic polymer chains (insoluble metal silicates) form throughout the aqueous phase and physically entrap the organic colloids within the microstructure of the product matrix. The water-soluble silicates then react with complex ions in the presence of a siliceous setting agent, producing amorphous, colloidal silicates (gels) and silicon dioxide, which acts as a precipitating agent. Most of the heavy metals in the waste become part of the silicate. Some of the heavy metals precipitate with the structure of the complex molecules. A very small percentage (estimated to be less than one percent) of the heavy metals precipitates between the silicates and is not chemically immobilized.

Because some organics may be contained in particles larger than the colloids, all of the waste is pumped through processing equipment, creating sufficient shear to emulsify the organic constituents. Emulsified organics are then solidified and discharged to a prepared area, where the gel continues to set. The resulting solids, though friable, encase any organic substances that may have escaped emulsification.

The system can be operated at 5 to 80 percent solids in the waste feed; water is added for drier wastes. Portions of the water contained in the wastes are involved in three reactions after treatment: (1) hydration, similar to that of cement reactions; (2) hydrolysis reactions; and (3) equilibration through evaporation. There are no side streams or discharges from this process.

Technology Performance

From fall 1989 through winter 1990, Chemfix Technologies, Inc.'s subsidiary, Chemfix Environmental Services, Inc. (CES), applied a high solids CHEMSET® reagent protocol approach to the treatment of about 30,000 cubic yards of heavy metal-contaminated waste. The technology met the goal of reducing leachable hexavalent chromium to below 0.5 ppm in the Toxicity Characteristic Leaching Procedure (TCLP), as well as the goal of producing a synthetic clay cover material with low permeability (less than 1×10^{-6} cm/sec). The technology also met the production goal of exceeding 400 tons per day. This included production during many subfreezing days in December, January, and March.

The CES technology was also effective in reducing the concentrations of lead and copper in the TCLP extracts. The concentrations in the extracts from the treated wastes were 94 to 99 percent less than those from the untreated wastes. Total lead concentrations in the raw waste approached 14 percent.

The CES solidification/stabilization technology performed well in several areas:

- The volume of the excavated waste material increased from 20 to 50 percent as a result of treatment;
- In the durability tests, the treated wastes showed little or no weight loss after 12 cycles of wetting and drying or freezing and thawing;
- The unconfined compressive strength of the wastes varied between 27 and 307 psi after 28 days. Permeability decreased by more than one order of magnitude;
- The air monitoring data suggest there was no significant volatilization of polychlorinated biphenyls (PCBs) during the treatment process; and
- The treated waste matrix displays good stability, a high melting point, and a friable texture. The matrix may be similar to soil, depending upon the water content of the feed waste.

Remediation Costs

Cost information is not available.

General Site Information

The technology was demonstrated in March 1989 at the Portable Equipment Salvage Company site in Clackamas, Oregon. EPA published the preliminary results in the SITE Demonstration Bulletin (October 1989), and also released a single draft report describing the demonstration and future application of this technology. EPA released the final demonstration report in early 1990. During the summer of 1990, CES engaged in another high solids project involving lead.

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IM-TECH Solidification / Stabilization Process

Organic Compounds, Heavy Metals, Ore and Grease in Soil and Sludge

Technology Description

The IM-TECH solidification/stabilization process immobilizes contaminants in soil or sludge by binding them into a concrete-like, leach-resistant mass. This treatment technology is suitable for soil and sludge contaminated with organic compounds, heavy metals, oil and grease. These wastes can be treated together or individually.

Contaminated soil or sludge can be excavated and/or treated in situ. If excavated, the waste is screened for oversized material and fed into a field blending unit. The blending unit may consist of concrete ready-mix trucks or huge batch plants capable of blending 100 tons per hour.

The solidification/stabilization process mixes hazardous wastes, cement or flyash, water, and a patented additive called Chloranan that encapsulates organic and inorganic molecules. First, the Chloranan and water are added to the blending unit. Next, the waste is added and the ingredients mixed for about one minute. Finally, the cement or flyash is added and the whole mass mixed for a final minute. After 12 hours, the treated output hardens into a concrete-like mass that binds and immobilizes the contaminant.

Technology Performance

The comparison of results from the seven-day, 28-day, nine month, and 22-month soil sample tests at Douglassville, Pennsylvania, are generally favorable. The physical test results were very good, with unconfined compressive strength between 220 to 1570 psi. Very low permeabilities were recorded, and the porosity of the treated wastes was moderate. Durability test results showed no change in physical strength after the wet/dry and freeze/thaw cycles. The waste volume increased by about 120 percent. However, refinements on the technology now restrict volumetric increases to the 15-25 percent range. Using less additives reduces strength, but toxicity reduction is not affected. There appears to be an inverse relationship between physical strength and the waste organic concentration.

The results of the leaching tests were mixed. The Toxicity Characteristic Leaching Procedure (TCLP) results of the stabilized wastes were very low; essentially all values of metals, volatile organics and semivolatile organics were below one ppm. Lead leachate concentrations dropped by a factor of 200 to below 100 ppb. Volatile and semivolatile organic concentrations, however, did not change from the untreated soil TCLP. Oil and grease concentrations were greater in the treated waste TCLPs than in the untreated waste, from less than two ppm up to four ppm.

The IM-TECH solidification/stabilization technology performed well in several areas:

- It solidified contaminated material with high concentrations (up to 25 percent) of organics; however, organic contaminants, including volatiles and base/neutral extractables, were not immobilized to any significant extent;
- It immobilized heavy metals -- in many instances, leachate reductions were greater than 100 fold;
- The physical properties of the treated waste exhibited high unconfined compressive strengths, low permeabilities, and good weathering properties; and
- The volume of treated soil increased.

Remediation Costs

The process, based on tests at Douglassville, Pennsylvania, was economical, with costs ranging from $40-60 per ton for processing heavy metals waste, and between $75-100 per ton for wastes with heavy organic content.

General Site Information

The technology was demonstrated in October 1987 at a former oil reprocessing plant in Douglassville, Pennsylvania. The site contained high levels of oil and grease (25 percent) and heavy metals (2.2 percent lead), and low levels of VOCs (100 ppm) and PCBs (75 ppm). A Technology Evaluation Report (September 1988) and Applications Analysis Report (May 1990) describing the completed demonstration are available from EPA's Center for Environmental Research Information (CERI). A report on long-term monitoring will be available by 1990.

Since the demonstration, the technology has been used to remediate a sludge with 85 percent oil from a refinery lagoon in Alaska, several organic sludges for refineries on the Gulf Coast, and a California Superfund site contaminated with very high levels of heavy metals.

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In Situ Solidification / Stabilization Process

Inorganic and Organic Compounds in Soil, Sediment, and Sludge

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Technology Description

This in situ solidification/stabilization process immobilizes organic and inorganic compounds in wet or dry soil, using reagents (additives) to produce a cement-like mass. This technology can be applied to soil, sediments, and sludge-pond bottoms contaminated with organic compounds and metals. The process has been laboratory-tested on soil containing polychlorinated biphenyls (PCBs), pentachlorophenol, refinery wastes, and chlorinated and nitrated hydrocarbons.

There are two basic components of this technology: (1) Geo-Con's deep soil mixing system (DSM), a system to deliver and mix the chemicals with the soil in situ; and (2) a batch mixing plant to supply the International Waste Technologies' (IWT) proprietary treatment chemicals. The DSM system can be used in almost any soil type; however, mixing time increases with fineness. It can be used below the water table and in soft rock formations. Large obstructions must be avoided.

The IWT additives generate a complex, crystalline, connective network of inorganic polymers. The structural bonding in the polymers is mainly covalent. The process involves a two-phased reaction in which the contaminants are first complexed in a fast-acting reaction, and then in a slow-acting reaction, where the building of macromolecules continues over a long period of time. The amount of additives used varies for each type of waste. Treatability tests are recommended.

The DSM system involves mechanical mixing and injection. The system consists of one set of cutting blades and two sets of mixing blades attached to a vertical drive auger, which rotates at approximately 15 rpm. Two conduits in the auger are used to inject the additive slurry and supplemental water. Additive injection occurs on the downstroke; further mixing takes place upon auger withdrawal. The treated soil columns are 36 inches in diameter, and are positioned in an overlapping pattern of alternating primary and secondary soil columns.

Technology Performance

Testing of the technology's performance at a PCB-contaminated site in Hialeah, Florida, indicated promising results:

- Immobilization of PCBs appears likely, but could not be confirmed because of low PCB concentrations in the untreated soil. Leachate tests on treated and untreated soil samples showed mostly undetectable PCB levels. Leachate tests performed one year later on treated soil samples showed no increase in PCB concentrations, indicating immobilization.

- Sufficient data were not available to evaluate the performance of the system with regard to metals or other organic compounds.

- Each of the test samples showed high unconfined compressive strength, low permeability, and low porosity. These physical properties improved when retested one year later, indicating the potential for long-term durability.

- The bulk density of the soil increased 21 percent after treatment. This increased the volume of treated soil by 8.5 percent and caused a small ground rise of one inch per treated foot of soil.

- The unconfined compressive strength (UCS) of the treated soil was satisfactory, with values up to 1,500 pounds per square inch (psi).

- The permeability of the treated soil was satisfactory, decreasing four orders of magnitude compared to the untreated soil, or 10^{-6} and 10^{-7} compared to 10^{-2} cm/sec.

- The wet/dry weathering test on treated soil was satisfactory. The freeze/dry weathering test of treated soil was unsatisfactory.

- The microstructural analysis, scanning electron microscopy (SEM), optical microscopy, and x-ray diffraction (XRD), showed that the treated material was dense, non-porous, and homogeneously mixed.

- The Geo-Con DSM equipment operated reliably.

This technology demonstration site was composed primarily of unconsolidated sand and limestone. The demonstration yielded several conclusions about the performance of the technology:

- Microstructural analyses of the treated soil indicated a potential for long-term durability. High unconfined compressive strengths and low permeabilities were recorded.

- Data provided by IWT indicate some immobilization of volatile and semivolatile organics. This may be due to organophilic clays present in the IWT reagent. There are insufficient data to confirm this immobilization.

- Performance data are limited outside of SITE demonstrations. The developer modifies the binding agent for different wastes. Treatability studies should be performed for specific wastes.

Remediation Costs

Remediation costs for this process are estimated at $194 per ton of contaminated soil for the one-auger machine used in the demonstration, and $111 per ton for a commercial four-auger operation.

General Site Information

EPA conducted a SITE demonstration at a PCB-contaminated site in Hialeah, Florida, in April 1988. Two 10 x 20-foot test sectors of the site were treated, one to a depth of 18 feet, and the other to a depth of 14 feet. Ten months after the demonstration, EPA performed long-term monitoring tests on the treated sectors. EPA published the Technology Evaluation Report and Applications Analysis Report.

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Soil-Cement Mixing Wall (S.M.W.)

Metals and Semivolatile Organic Compounds in Soil

Technology Description

The Soil-Cement Mixing Wall (S.M.W.) technology involves the in situ fixation stabilization and solidification of soil contaminated with metals and semivolatile organic compounds, including pesticides, polychlorinated biphenyls (PCBs), phenols, and polyaromatic hydrocarbons (PAHs). Multi-axis overlapping hollow stem augers, mounted on a crawler-type base machine, inject solidification/stabilization agents and blend them with the contaminated soil in situ.

The machine can treat 90 to 140 cubic yards of soil per eight-hour shift at depths up to 100 feet. The in situ solidification/stabilization technology produces a monolithic block down to the treatment depth. The volume increase ranges from 10 to 30 percent, depending on the nature of the soil matrix and the amount of fixation reagents and water required for treatment.

This technique has been used in mixing soil, cement, or chemical grout for more than 18 years on various construction applications, including cutoff walls and soil stabilization.

Technology Performance

This project was accepted into the SITE Demonstration Program in June 1989. Site selection is currently underway.

Remediation Costs

Cost information is not available.

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Solidification / Stabilization

Organics and Inorganics in Soil, Sludge, and Liquid

Technology Description

This solidification/stabilization technology applies proprietary bonding agents to soil, sludge, and liquid wastes containing volatile or semi-volatile organic and inorganic contaminants to fix pollutants within the wastes. The treated waste is then mixed with cementitious materials and placed in a stabilizing matrix. The specific reagents used are custom-selected based on the particular waste to be treated. The resultant material is a high-strength, non-leaching monolith that can be placed into the ground.

This process uses standard engineering and construction equipment. Since the type and dose of reagents depend on the waste's characteristics, treatability studies and site investigations must be conducted to determine the proper reagent mix. The process begins with a front end loader and/or a backhoe excavating the waste material.

Material containing large pieces of debris must be prescreened. The waste is then placed, in measured quantities, into a pug mill or other mixer, where it is mixed with a controlled amount of water and reagent. From there, the waste-reagent mixture is transferred to the cement batcher, where it is mixed with dry blends of a pozzolanic mixture. The operation does not generate waste byproducts.

Technology Performance

EPA is in the process of selecting a site for the technology demonstration. To date, this technology has treated a wide variety of waste streams consisting of soil, sludge, and raw organic streams, such as lubricating oil, aromatic solvents, evaporator bottoms, chelating agents, and ion exchange resins, with contaminant concentrations ranging from parts per million (ppm) levels to 40 percent by volume. The technology can also be applied to mixed wastes containing radioactive materials along with organic and inorganic contaminants.

Remediation Costs

Cost information is not available.

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Solidification / Stabilization with Silicate Compounds

Organics and Inorganics in Ground Water, Soil, and Sludge

Technology Description

This technology uses silicate compounds to fix and solidify soil and sludge contaminated with metals, cyanide, fluorides, arsenates, ammonia, chromates, and selenium in unlimited concentrations. This technology also removes organics from contaminated water. Higher weight organics in ground water, soil, and sludge, including halogenated, aromatic, and aliphatic compounds, can also be treated by this process. However, the process is not as successful for low molecular weight organics such as alcohols, ketones, glycols, and volatile organics. For soil and sludge, proprietary silicate reagents selectively adsorb organic and inorganic contaminants before the waste is mixed with a cement-like material to form a high-strength, non-leaching cement block (monolith). For water, the same reagents can be used in conjunction with granular activated carbon to remove organics from the ground water. The resulting waste material is then solidified by the first technology.

In this combined technology, the type and dose of reagents depend on the waste characteristics. Treatability studies and site investigations are conducted to determine reagent formulations.

The process begins with pretreatment of the contaminated waste material. Coarse material is separated from fine material and sent through a shredder or crusher to reduce the material to the size required for the solidification technology. The waste is then loaded into a batch plant, weighed, and the proportional amount of silicate reagent is added. This mixture is conveyed to a concrete mixing truck, pug mill or other mixing equipment where water is added and the mixture is thoroughly blended. The treated material is then placed in a confining pit on-site for curing, or cast into molds for transport and disposal off-site.

A self-contained mobile filtration pilot facility is used to treat organic-contaminated ground water. The contaminated water is passed through a column filter containing the silicate reagent to separate the high molecular weight organics from the water. The effluent from this column filter is then passed through a second column filter containing granulated activated carbon to remove the low molecular weight organics.

Technology Performance

A demonstration of this technology was scheduled to occur during October or November 1990 at a wood treating site near Fresno, California. Contaminants at the site include pentachlorophenol, chromium, copper, and arsenic. Results are currently unavailable.

Remediation Costs

Cost information is not available.

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Soliditech Solidification / Stabilization Process

Organic and Inorganic Compounds, Metals, Ore and Grease in Soil and Sludge

Technology Description

This solidification/stabilization process immobilizes contaminants, particularly organic compounds, metals, inorganic compounds, and oil and grease, in soil and sludge by binding them in a concrete-like, leach-resistant matrix. Wastes treated during the demonstration were soil, filter cake, and oily wastes from an old storage tank. These wastes were contaminated with petroleum hydrocarbons, polychlorinated biphenyls (PCBs), other organic chemicals, and heavy metals. Batch mixers of various capacities are available to treat different volumes of waste.

Contaminated waste materials are collected, screened to remove oversized material, and introduced to the batch mixer. The waste material is then mixed with: (1) water; (2) Urrichem, a proprietary chemical reagent; (3) proprietary additives; and (4) pozzolanic material, kiln dust, or cement; cement was used for the demonstration. Once thoroughly mixed, the treated waste is discharged from the mixer.

Technology Performance

The Soliditech demonstration at the Imperial Oil Company/Champion Chemical Company Superfund site in Morganville, New Jersey, presented several key findings:

- Chemical analyses of extracts and leachates showed that heavy metals present in the untreated waste were immobilized;
- Solid and liquid wastes with high organic content (up to 17 percent) as well as oil and grease were solidified;
- Volatile organic compounds in the original waste were not detected in the treated waste;
- Treated waste is a solidified mass with significant unconfined compressive strength, high stability, and a rigid texture similar to that of concrete. Physical test results of the solidified waste samples showed: (1) unconfined compressive strengths ranged from 390 to 860 psi; (2) very little weight loss after 12 cycles of wet/dry and freeze/thaw durability tests; (3) low permeability of the treated waste; and (4) increased density after treatment;
- The solidified waste increased in volume by an average of 22 percent. The bulk density of the waste material increased by approximately 35 percent due to solidification;
- Semivolatile organic compounds (phenols) were detected in the treated waste and the Toxicity Characteristic Leaching Procedures (TCLP) extracts from the treated waste but not in the untreated waste or its TCLP extracts. The presence of these compounds is believed to result from chemical reactions in the waste treatment mixture;
- Oil and grease content of the untreated waste ranged from 2.8 to 17.3 percent (28,000 to 173,000 ppm). Oil and grease content of the TCLP extracts of the solidified waste ranged from 2.4 to 12 ppm;
- The pH of the solidified waste ranged from 11.7 to 12.0. The pH of the untreated waste ranged from 3.4 to 7.9;
- PCBs were not detected in any extracts or leachates of the treated waste; and

- Visual observation of solidified waste showed dark inclusions approximately 1 mm in diameter. Ongoing microstructural studies are expected to confirm that these inclusions are encapsulated wastes.

A Technology Evaluation Report was published in February 1990 in two volumes: Volume I (EPA/540/5-89/005A) is the report itself and Volume II (EPA/540/5-89/005B) contains the data that accompanies the report. An Applications Analysis Report was scheduled for publication in late November 1990.

Remediation Costs

Cost information is not available.

General Site Information

EPA demonstrated the Soliditech process in December 1988 at the Imperial Oil Company/Champion Chemical Company Superfund site in Morganville, New Jersey. This location formerly contained both chemical processing and oil reclamation facilities.

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Stabilization with Lime

Hydrocarbons and Organics in Sludge

Technology Description

This technology uses lime to stabilize acidic sludge containing at least five percent hydrocarbons (typical of sludge produced by recycling lubricating oils). The technology can also stabilize waste containing up to 80 percent organics. The process tolerates low levels of mercury and moderate levels of lead and other toxic metals. No hazardous materials are used in the process. The lime and other chemicals are specially prepared to significantly improve their reactivity and other key characteristics.

Sludge is removed from a waste pit using conventional earthmoving equipment and mixed with lime in a separate blending pit. The temperature of the material in the blending pit rises for a brief time to about 100° C, creating some steam. After 20 minutes, almost all of the material is fixed, however, the chemicals mixed in the sludge continue to react with the waste for days. The volume of the waste is increased by 30 percent by adding lime.

The fixed material is stored in a product pile until the waste pit has been cleaned. The waste is then returned to the pit and compacted to a permeability of 10^{-10}cm/sec.

Technology Performance

EPA is seeking a suitable site to demonstrate this technology. A SITE demonstration is planned for the spring or summer of 1991.

Remediation Costs

Cost information is not available.

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Other Physical Treatment

Carver-Greenfield Process for Extraction of Oily Waste

Oil-Soluble Hazardous Compounds in Sludge and Soil

Technology Description

The Carver-Greenfield Process® is designed to separate materials into their constituent solid, oil (including oil-soluble substances), and water phases. It is primarily intended for soils and sludges contaminated with oil-soluble hazardous compounds. The technology uses a food-grade "carrier oil" to extract the oil-soluble contaminants. Pretreatment is necessary to achieve particle sizes less than 3/8-inch.

The carrier oil, with a boiling point of 400° F, typically is mixed with waste sludge or soil and the mixture is placed in the evaporation system to remove any water. The oil serves to fluidize the mix and maintain a low slurry viscosity to ensure efficient heat transfer, allowing virtually all of the water to evaporate.

Oil-soluble contaminants are extracted from the waste by the carrier oil. Volatile compounds present in the waste are also stripped in this step and condensed with the carrier oil or water. After the water is evaporated from the mixture, the resulting dried slurry is sent to a centrifuging section that removes most of the carrier oil from the solids.

After centrifuging, residual carrier oil is removed by a process known as hydroextraction. The carrier oil is recovered by evaporation and steam stripping. The hazardous constituents are removed from the carrier oil by distillation. This stream can be incinerated or reclaimed. In some cases, heavy metals in the solids will be complexed with hydrocarbons and will also be extracted by the carrier oil.

Technology Performance

The process has been successfully tested in a pilot plant on refinery "slop oil," consisting of 72 percent water, and on a mixed refinery waste consisting of dissolved air flotation sludge, API separator bottoms, tank bottoms, and biological sludge. EPA has identified the PAB Oil site in Louisiana as a potential site for demonstrating this technology. The PAB oil site contains petroleum wastes and contaminated soils, and a demonstration was tentatively planned for January 1991.

The Carver-Greenfield process can be used to treat sludge, soil, and other water-bearing wastes containing oil-soluble hazardous compounds, including PCBs, PNAs, and dioxins. The process has been commercially applied to municipal wastewater sludge, paper mill sludge, rendering waste, pharmaceutical plant sludge, and many other wastes.

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Catalytic Decontamination

Volatile Organic Compounds (VOC) in Ground Water

Technology Description

This catalytic decontamination process is a closed system that treats volatile organic compounds in ground water producing innocuous end products. This technology can be useful when cross media transfer of the contamination, which may occur with other processes, such as air stripping, is unacceptable. This technology is primarily a ground-water restoration technique, although surface water can be treated as well. It is especially applicable for highly contaminated waters such as leachates.

The ULTROX system used in the pilot study consists of two "loops." The first loop consists of air drying, ozone generation, and injection of the ozone into the vapor-liquid contact tank. Air effluent passes through a catalytic destruction unit and returns to the air drier. The second loop is open and consists of a water inlet from the ground-water source, pretreatment, introduction into the vapor-liquid contact tank, and discharge. The water pretreatment might consist of filtering, water softening, iron removal, or defoaming.

This technology has a number of advantages:

- The process is closed circuit, i.e., there is no air effluent;
- It operates at negative air pressure, thus, reducing the risk of accidental contamination due to leaks; and
- It is a destructive, rather than a cross media transfer technique.

Despite these advantages, this technology also has limitations:

- The method might not be cost effective with respect to methods that have air effluents;
- When treating high concentrations, a potentially large consumption of ozone will result;
- When treating anoxic leachates, reduced metal compounds are likely to be present;
- These reduced metal compounds will react with the ozone and can form insoluble precipitates as well as result in large ozone consumption;
- The metal precipitates could require extensive system cleaning;
- The method requires considerable energy for the generation of UV light, dry air, ozone, pumps, and blowers; and
- Biofouling can occur on the UV light tubes.

Technology Performance

The results from a small-scale pilot test conducted at Fort Dix, New Jersey were both positive and negative:

- Although total organic carbon concentration was not reduced, the concentration of volatile halogenated organics (VHO) was reduced up to 90 percent; and
- Without the inclusion of UV light in the treatment, the VHO concentration was reduced, but methylene chloride was not affected and dichloroethanes were not reduced below detection limits.

Remediation Costs

Based on limited experience to date, the operating and maintenance costs of this method have not been developed in detail, but are expected to be in the range of $1 to $8 per 1,000 gallons, depending upon the concentration of the contaminants and the amount of pretreatment required. Uninstalled equipment for treating 50,000 gpd of ground water, with an organic halide concentration in the range of 75 to 100 g/L, would cost in the range of $150,000 to $200,000.

General Site Information

A small-scale pilot testing (1 to 10 drums) has been conducted at Fort Dix, New Jersey.

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Catalytic Ozone Oxidation

Organics and Inorganics in Soil, Solid, Sludge, Leachates, Ground Water

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Technology Description

This technology is designed to treat soils with organic and inorganic contaminants. The technology is a two-stage process: the first stage extracts the contaminants from the soil, and the second stage oxidizes contaminants present in the extract. The extraction is carried out using ultrapure water and ultrasound. Oxidation involves ozone, ultraviolet light, and ultrasound. The treatment products of this technology are decontaminated soil and inert salts.

After excavation, contaminated soil is passed through a 1-inch screen. Soil particles retained on the screen are crushed using a hammermill and sent back to the screen. Soil particles passing through the screen are sent to a soil washer, where ultrapure water extracts the contaminants from the screened soil. Ultrasound acts as a catalyst to enhance soil washing. Typically, 10 volumes of water are added per volume of soil, generating a slurry of about 10-20 percent solids. This slurry is conveyed to a solid/liquid separator, such as a centrifuge or cyclone, to separate the decontaminated soil from the contaminated water. The decontaminated soil can be returned to its original location or disposed of appropriately.

After the solid/liquid separation, any oil present in the contaminated water is recovered using an oil/water separator. The contaminated water is ozonated prior to oil/water separation to aid in oil recovery. The water then flows through a filter to remove any fine particles. After the particles are filtered, the water flows through a carbon filter and a deionizer to reduce the contaminant load on the multi-chamber reactor.

In the multi-chamber reactor, ozone gas, ultraviolet light, and ultrasound are applied to the contaminated water. Ultraviolet light and ultrasound catalyze the oxidation of contaminants by ozone. The treated water (ultrapure water) flows out of the reactor to a storage tank and is reused to wash another batch of soil. If makeup water is required, additional ultrapure water is generated on-site by treating tap water with ozone and ultrasound.

This treatment system is also equipped with a carbon filter to treat the off-gas from the reactor. The carbon filters are biologically activated to regenerate the spent carbon in-situ.

System capacities range from one cubic foot of solids per hour, with a water flow rate of one gallon per minute, to 27 cubic yards of solids per hour, with a water flow rate of 50 gallons per minute. The treatment units available for the SITE demonstration can treat 1 to 5 cubic yards of solids per hour.

Technology Performance

This technology was tentatively scheduled for a demonstration in late 1990. This technology can be applied to soil, solid, sludge, leachates and ground water containing organics such as PCB, PCP, pesticides and herbicides, dioxins, and inorganics, including cyanides. The technology could effectively treat total contaminant concentrations ranging from 1 ppm to 20,000 ppm. Soil and solids greater than 1 inch in diameter need to be crushed prior to treatment.

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Chemtact^{TM} Gaseous Waste Treatment

Organics and Inorganics in Waste Streams

Technology Description

The Chemtact^{TM} system uses gas scrubber technology to remove gaseous organic and inorganic contaminants through efficient gas-liquid contacting. This technology can be used on gaseous waste streams containing a wide variety of organic or inorganic contaminants, but is best suited for volatile organic compounds. The system is applicable for use with source processes that generate a contaminated gaseous exhaust, such as air stripping of ground water or leachate, soil aeration, or exhausts from driers or incinerators.

Droplets of a controlled chemical solution are dispersed by atomizing nozzles within the scrubber chamber. Very small droplet sizes (less than 10 microns), along with a longer retention time than traditional scrubbers, results in a once-through system that generates low volumes of liquid residuals. These residuals are subsequently treated by conventional techniques.

Gas scrubbing is a volume reduction technology that transfers contaminants from the gas phase to a liquid phase. The selection of absorbent liquid is based on the chemical characteristics of the contaminants.

Two mobile pilot units are currently available: a two-stage, 800 cubic feet per minute (cfm) system; and a one-stage, 2,500 cfm system. This equipment is trailer-mounted and can be transported to waste sites.

Technology Performance

EPA is currently locating a suitable site to demonstrate this technology.

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Freezing Separation

Organics and Inorganics in Aqueous Streams

Technology Description

This freeze crystallization technology will remove both organics and inorganics from contaminated aqueous streams. It works on both surface water and ground water, as well as directly on process wastes and mixed (radioactive and hazardous) wastes. Freeze technologies can process all contaminant types in a single stage. It is also capable of concentrating residuals to higher concentrations than other liquid separation processes.

This process is applicable to free liquids, whether the liquid is water or an organic solvent. It can be used in conjunction with other processes to treat wastes contained in non-aqueous media. For example, contaminated soils can be washed to transfer the contaminant into a liquid medium. The low concentrations in the washing medium are concentrated by freezing to allow by-product recovery or more economical final destruction.

The freeze crystallization process operates on the principle that when water freezes, the crystal structure that forms naturally excludes contaminants from the water molecule matrix. In this freeze crystallization process, refrigerant is injected directly into the feed, thus, removing heat until a phase change from liquid to solid is achieved. Pure crystals of solute and solvent form separately and are separated from each other by gravity. The crystals are recovered and washed with melt-water to remove any adhering contaminants and then melted in a heat pump cycle before being discharged from the plant.

Mixed liquid waste enters the system through the feed heat exchanger, where it is cooled within a few degrees of its freezing temperature. The cooled feed then enters the crystallizer, where it is mixed directly with boiling refrigerant. The water molecules are crystallized in the stirred solution and are maintained at a uniform ice concentration by continuous removal of ice slurry (a combination of ice crystals and liquid) from the crystallizer. The slurry is pumped to a eutectic separator (also called a growth tank) where gravity segregates the crystal of solvent and solute into different streams. A heat pump/refrigeration cycle removes refrigerant vapor from the crystallizer and compresses it so that it will give up its heat to melt the purified crystals.

Ice slurry from the growth tank is pumped to the crystal separator, where ice crystals form a porous pack. The liquid from the slurry is drained by gravity from the wash column via screened openings, and is then returned to the growth tank to transport more ice. Hydraulic forces generated by the flow of liquid to the screens in the middle of the ice pack propel the ice pack upward in the crystal separator. Melted product is used to transport the ice to a melter/condenser, where the slurry is melted and where hot refrigerant gas is condensed.

All refrigerants are soluble in water to some degree. Consequently, decanters and strippers are used to remove this refrigerant from the melt, the concentrate, and any other liquid phases produced from the process prior to their discharge from the plant. The strippers operate under a vacuum and contain heaters that generate low-pressure steam to enhance refrigerant removal, if necessary.

Technology Performance

This project was accepted into the SITE Demonstration Program in July 1988. Treatability studies have been completed. A demonstration of this technology was scheduled for early 1991 at the Stringfellow Superfund Site in Glen Avon, California.

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Geosafe Process

Inorganics in Soils and Sludges

Technology Description

The Geosafe in situ vitrification (ISV) process can be used to destroy or remove organics and/or immobilize inorganics in contaminated soils or sludges. Geosafe has performed more than 90 tests of various scales applying ISV on polychlorinated biphenyl (PCB) wastes, industrial lime sludge, dioxins, metal plating wastes and other solid combustibles and liquid chemicals. The ISV process uses an electrical network to melt soil or sludge at temperatures of 1600 to 2000° C; thus, destroying organic pollutants by pyrolysis. Inorganic pollutants are incorporated within the vitrified mass, which has properties of glass.

The vitrification process begins by inserting large electrodes into contaminated zones containing sufficient soil to support the formation of a melt. An array (usually square) of four electrodes is placed to the desired treatment depth in the volume to be treated. Because soil typically has low conductivity, flaked graphite and glass frit are placed on the soil surface between the electrodes to provide a starter path for electric current. The electric current passes through the electrodes and begins to melt soil at the surface. As power is applied, the melt continues to grow downward, at a rate of one to two inches per hour. Individual settings (each single placement of electrodes) may grow to encompass a total melt mass of 1000 tons and a maximum width of 30 feet. Single setting depths as great as 30 feet are considered possible. Depths of 17 feet have been achieved to date with the existing large-scale ISV equipment. Adjacent settings can be positioned to fuse to each other and to completely process the desired volume at a site. Stacked settings to reach deep contamination are also possible.

Both the organic and inorganic airborne pyrolysis byproducts are captured in a hood, which draws the contaminants into an off-gas treatment system that removes particulates and other pollutants of concern. Air flow through the hood is controlled to maintain a negative pressure. An ample supply of air provides excess oxygen for combustion of any pyrolysis products and organic vapors from the treatment volume. The off-gases, combustion products, and air are drawn from the hood (by induced draft blower) into the off-gas treatment system, where they are treated in several ways: (1) quenching; (2) pH controlled scrubbing; (3) dewatering (mist elimination); (4) heating (for dewpoint control); (5) particulate filtration; and (6) activated carbon adsorption (Figure 2).

Because the void volume present in particulate materials (20-40 percent for typical soils) is removed during processing, a corresponding volume reduction occurs. Volume is further reduced as some materials present in the soil, such as humus and organic contaminants, are removed as gases and vapors during processing.

The ISV system is mounted on three semi-trailers for transport to a site. Electric power is usually taken from a utility distribution system at transmission voltages of 125 or 138 kilovolts (kV); power may also be generated on-site by a diesel generator. The electrical supply system has an isolated ground circuit to provide appropriate operational safety.

In saturated soils or sludges, the initial application of the electric current must reduce the moisture content before the vitrification process can begin. This increases energy consumption and associated costs. Also, sludges must contain a sufficient amount of glass-forming material (non-volatile, non-destructible solids) to produce a molten mass that will destroy or remove organic and immobilize inorganic pollutants. The ISV process is limited: (1) individual void volumes cannot exceed 150 cubic feet; (2) rubble cannot exceed 10 percent by weight; and (3) combustible organics in the soil or sludge cannot exceed 5-10 weight percent, depending upon the heat value. These limitations must be addressed for each site.

Technology Performance

Based on tests conducted by the technology vendor, the large-scale ISV system melts soil at a rate of four to six tons per hour. After cooling, the process results in the formation of a vitrified silicate glass monolith with a microcrystalline structure. This monolith possesses excellent structural and environmental properties.

Remediation Costs

Cost information is not available.

General Site Information

ISV technology has been selected as part of a Record of Decision (ROD) or equivalent for use at eight sites within the U.S. and one site in Europe. EPA's SITE Program is planning a technology demonstration at an unspecified site.

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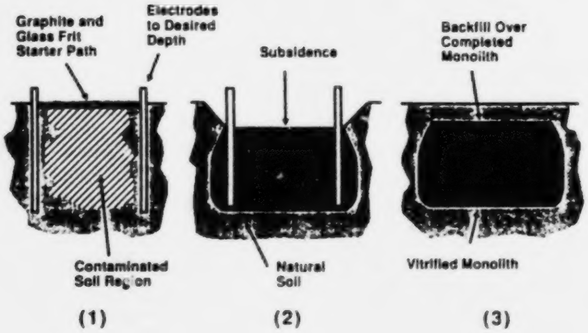
Graphite and Glass Frit Starter Path
Electrodes to Desired Depth
Subsidence
Backfill Over Completed Monolith
Contaminated Soil Region
Natural Soil
Vitrified Monolith
(1)
(2)
(3)

In Situ Vitrification

Organics, Inorganics, and Radionuclides in Soils

Technology Description

The in situ vitrification (ISV) process fixes fission products and immobilizes or destroys hazardous chemicals in soils at mixed hazardous waste sites. This technology can be applied to radionuclides, heavy metals, and hazardous organic-contaminated soil.

ISV is the conversion of contaminated soil into a durable glass and crystalline waste form through melting the soil by joule heating. Contaminants are destroyed by or immobilized in molten glass (melted soil). Soil is melted by electrical energy from electrodes that are placed in the ground. Off-gas from this process is treated by conventional off-gas treatment methods.

This technology has a number of benefits. Specifically, ISV may safely immobilize or destroy both radioactive and hazardous chemicals before they impact the ground water or other ecosystems. It is applicable to soils contaminated with fission products, transuranics, hazardous metals, and hazardous organics. It reduces the risk to the public by immobilizing or destroying radioactive and hazardous materials in the soil. Finally, in situ treatment poses a lower potential risk to workers than traditional treatments because contaminants are not brought to the surface. This technology, however, has not yet been demonstrated at depths beyond twenty feet.

Technology Performance

A small-scale ISV test at DOE's Hanford Nuclear Reservation produced the following conclusions:

- Injection of a conductive glass frit and sodium silicate slurry into the rocky layer below the crib enhances the downward penetration of the ISV melt;
- Wood pyrolysis rates calculated from the small-scale test results indicate that the increased heat load to the off-gas system from the wooden timbers in the crib will raise the off-gas temperature to about 300 degrees Celsius, well within the operating limits of the off-gas system and hood;

A full-scale field demonstration at Hanford was also successful:

- The product passed the TCLP and reduced the risk to workers and the public;
- Waste volume was reduced by 25 percent;
- ISV can treat 100 tons of soil per day;
- Residual wastes include scrub solution from off-gas treatment (approximately 0.25 gallons per ton of waste), treated waste is a delistable glass and crystaline block; and
- Obsidian-like glass and crystalline product will not require long term monitoring.

Remediation Costs

Approximately $150 to $350 per ton of soil.

General Site Information

A field demonstration at DOE waste tanks was conducted at the Hanford Nuclear Reservation, Washington. A one meter diameter by one meter tall instrumented underground tank was melted in September 1990. Hazardous constituents of the tank, the tank itself and soil beneath the tank were converted to a 30 ton block which passes the TCLP leach rate criteria. A 6000 gallon tank will be vitrified by summer 1991.

The 116-B-6A CRIB full-scale field demonstration was conducted at the 100-B Area in Hanford between 1988 and 1991. The site in the crib contained approximately 900 mCi of Strontium-90, 150 mCi of Cesium-137, and a mixture of other hazardous constituents including chromium and lead.

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Membrane Microfiltration

Organic, Inorganic, and Oily Wastes in Ground Water, Wastewater, and Soil

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Technology Description

This microfiltration system is designed to remove solid particles from liquid wastes, forming filter cakes typically ranging from 40 to 60 percent solids. The system can be manufactured as an enclosed unit, requires little or no attention during operation, is mobile, and can be trailer-mounted.

This treatment technology is applicable to hazardous waste suspensions, particularly liquid heavy metal- and cyanide-bearing wastes (such as electroplating rinsewaters); ground water contaminated with heavy metals; landfill leachate; and process wastewaters containing uranium. The technology is best suited for treating wastes with solid concentrations less than 5,000 parts per million; otherwise, the cake capacity and handling become limiting factors. The developers claim the system can treat any type of solid, including inorganics, organics, and oily wastes with a wide variety of particle sizes. Moreover, because the unit is enclosed, the system is said to be capable of treating liquid wastes containing volatile organics.

The DuPont/Oberlin microfiltration system uses Oberlin's automatic pressure filter combined with DuPont's special Tyvek filter material (Tyvek T-980) made of spun-bonded olefin. The filter material is a thin, durable plastic fabric with tiny openings (about one ten-millionth of a meter in diameter) that allow water or other liquids, along with solid particles smaller than the openings, to flow through. Solids in the liquid stream that are too large to pass through the openings accumulate on the filter, and can be easily collected for disposal.

The automatic pressure filter has two chambers: an upper chamber for feeding waste through the filter, and a lower chamber for collecting the filtered liquid (filtrate). At the start of a filter cycle, the upper chamber is lowered to form a liquid-tight seal against the filter. The waste feed is then pumped into the upper chamber and through the filter. Filtered solids accumulate on the Tyvek surface, forming a filter cake, while filtrate is collected in the lower chamber. Air is fed into the upper chamber at about 45 pounds per square inch, and used to further dry the cake and remove any liquid remaining in the upper chamber. When the cake is considered to be dry, the upper chamber is lifted and the filter cake is automatically discharged. Clean filter material is then drawn from a roll into the system for the next cycle. Both the filter cake and the filtrate can be collected and treated further prior to disposal if necessary.

Technology Performance

The DuPont/Oberlin microfiltration system was recently demonstrated at the Palmerton Zinc Superfund site in Palmerton, Pennsylvania. The system was tested for treating a shallow aquifer contaminated with dissolved heavy metals (such as cadmium, lead, and zinc). Pilot studies on ground water at this site have shown that the microfiltration system can produce a 35 to 45 percent-solids filter cake, and a filtrate with non-detectable levels of heavy metals.

During this demonstration the DuPont/Oberlin microfiltration system the results were positive:

- Zinc and total suspended solids removal efficiencies ranged from 99.75 to 99.99 percent;
- Solids in the filter cake ranged from 30.5 to 47.1 percent;
- Dry filter cake in all test runs passed the RCRA permit filter liquids test;
- Filtrate met the applicable National Pollution Discharge Elimination System standard for zinc, but exceeded the standard for pH; and

- A composite filter cake sample passed the EP Toxicity and TCLP tests for metals.

EPA prepared a Demonstration Bulletin summarizing the results of the demonstration in August 1990 and is currently finalizing a Technology Evaluation Report, Applications Analysis Report, and video of the demonstration.

General Site Information

This technology was demonstrated over a four-week period in April and May 1990 at the Palmerton Zinc Superfund site in Palmerton, Pennsylvania.

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Precipitation, Microfiltration, and Sludge Dewatering

Heavy Metals, Oil and Grease, Bacteria in Water

Technology Description

This technology is applicable to water containing heavy metals, pesticides, oil and grease, bacteria, suspended solids, and constituents that can be precipitated into particle sizes greater than 0.1 micron. The system can handle waste streams containing up to 5% (50,000 ppm) contaminant, producing a filtrate with less than 1.0 ppm and a semi-dry cake of 40-60%. Nonvolatile organics and solvents can also be treated by adding powdered adsorbents. Soils and sludge can be decontaminated through acid leaching of the metals followed by precipitation and microfiltration. Lime sludges from municipal, industrial, and power plant clarifiers can also be treated using this process.

In the first step of this process, heavy metals are chemically precipitated. The precipitates, along with all particles down to 0.2 - 0.1 micron, are filtered through a unique fabric crossflow microfilter (EXXFLOW). The concentrated stream is then dewatered in an automatic tubular filter press of the same fabric material (EXXPRESS). EXXPRESS filter cakes of up to 60 percent solids (weight per weight) are possible.

Microfiltration involves a proprietary woven polyester array of tubes. Waste effluent is pumped into the tubes and forms a dynamic membrane, which produces a high quality filtrate removing all particle sizes below 0.2 - 0.1 micron. The membrane is continually cleaned by the flow velocity, thereby preventing flux reduction. Metals are removed via precipitation by adjusting the pH in the EXXFLOW feed tank. The metal hydroxides or oxides form the dynamic membrane with any other suspended solids. The concentrated stream will contain up to 5 percent solids for discharge to the EXXPRESS. Water recoveries are above 90 percent in most cases.

Other constituent removals are possible, using seeded slurry methods in EXXFLOW: hardness can be removed using lime; oil and grease can be removed using adsorbents; and nonvolatile organics and solvents can be removed using seeded, powdered activated carbon or powdered ion exchange adsorbents. The concentrate stream produced by EXXFLOW enters EXXPRESS with the discharge valve closed. A semi-dry cake up to 1/4 inch thick is formed on the inside of the tubular cloth. When the discharge valve is opened, rollers on the outside of the tubes move to form a venturi within the tube. The venturi creates an area of high velocity within the tubes, which aggressively cleans the cloth and discharges the cake in chip form onto a wedge wire screen. The discharge water is recycled back to the feed tank. In cases where the solids in the raw feed water are extremely high, EXXPRESS can be used first, with EXXFLOW acting as a final polish for the product water.

In special circumstances, chelating agents can also be used to remove a particular metal. The leached slurry containing the solubilized metals is separated by an automatic cake discharge tubular filter press. The resulting filtrate is chemically treated to precipitate the heavy metals in hydroxide form.

Residual organic contamination in this precipitate can be removed with activated carbon. Heavy metals in the precipitate are separated and concentrated by microfiltration, using an innovative and flexible woven textile material that can separate particles as small as 0.1 microns. The process is capable of handling widely varying incoming solids concentrations.

The demonstration unit is transportable and is skid-mounted. The unit is designed to process approximately 30 pounds of solids per hour.

Technology Performance

Bench-scale tests of this technology have been conducted. The first application was scheduled in late 1990 on acid mine drainage at the Iron Mountain Mine Superfund Site in Redding, California.

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DEPARTMENT OF THE AIR FORCE
MCMXLVII
UNITED STATES OF AMERICA

Rotary Air Stripping

Volatile Contaminants in Ground Water

Technology Description

A rotary air stripper is a vapor and liquid contactor which uses centrifugal force to push contaminated water through packing material while air is pushed counter current to the flow of water. The centrifugal force results in a high mass transfer rate of the contaminant from the water to the air. The main advantage of this rotary air stripper is the reduction of the height of the stripping equipment. Large, tall towers are inherent in conventional packed column air stripping.

Technology Performance

In the first tests with a rotary air stripper conducted at the Traverse City Coast Guard Station, a 100-gpm rotary air stripper showed removal of the contaminant as a function of the liquid to gas ratio and the speed (rpm) of the spinning rotor. The data showed that the removal efficiency increased with an increase in the gas-to-liquid ratio up to a value of about 30 (vol/vol). Above this value, minimal increases in removal efficiencies were realized with increased gas-to-liquid ratios. A similar phenomenon was observed when assessing the effect of the rotor speed on the removal efficiency. Increasing the rotation above approximately 600 rpm produced minimal changes in the removal efficiency. In all the tests, high removal efficiencies (greater than 99 percent) were achieved with the highly volatile contaminants, while relatively low removal efficiencies were observed for the less volatile contaminants. In these tests, only one size and type of packed rotor was used, and only influent and effluent data could be taken.

In the second tests, conducted at Elgin AFB, three different sizes of rotors and two different types of packing materials were used, along with an internal sampling mechanism. Using the different packed rotors, data was obtained to develop and compare equations for predicting the mass transfer pressure drops, and power consumption of the rotary air stripper. The equations can be used to design the size, rotating speed, air-to-water ratios, and energy necessary for a rotary air stripper to meet site specific performance requirements.

The only limitation noted was that plugging occurred due to mineral deposits in the rotors at one site where the ground water has a very high iron content (approximately 9 ppm).

General Site Information

Field tests have been conducted at Elgin AFB and at the U.S. Coast Guard Station at Traverse City, Michigan.

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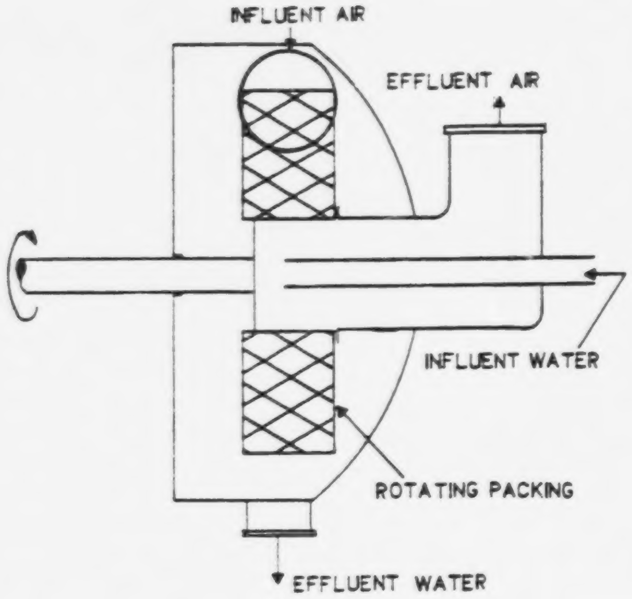
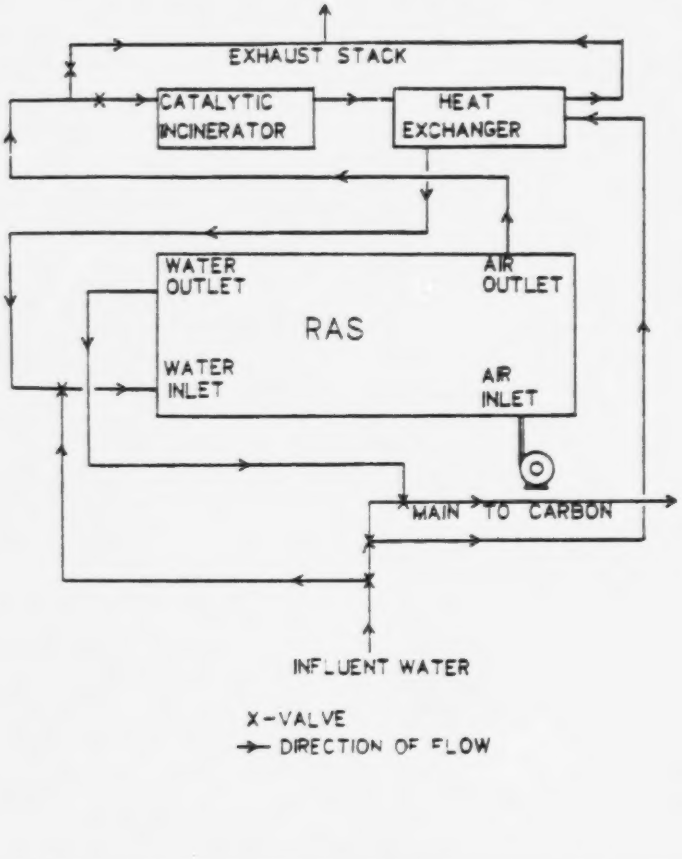

INFLUENT AIR
EFFLUENT AIR
INFLUENT WATER
ROTATING PACKING
EFFLUENT WATER


EXHAUST STACK
CATALYTIC INCINERATOR
HEAT EXCHANGER
WATER OUTLET
AIR OUTLET
RAS
WATER INLET
AIR INLET
MAIN TO CARBON
INFLUENT WATER
X-VALVE
DIRECTION OF FLOW

Treatment with Ultra Violet, Hydrogen Peroxide, and Ozone

Trichloroethene in Ground Water

Technology Description

This oxidation process uses ozone, ultraviolet radiation, and hydrogen peroxide for the treatment of ground water contaminated with trichloroethene (TCE).

Technology Performance

Results from the full-scale, advanced oxidation process tested at the DOE Kansas City plant were mostly inconclusive:

- The plant is effective in the destruction of individual volatile organic compounds but seems to reach a plateau for gross parameters such as total organic carbon and total chlorinated hydrocarbons;
- The plant has been out of service for maintenance and repair approximately 30 percent of the time;
- The flow rate has averaged approximately 15 percent of the design flow rate, so the determination of costs has been inconclusive; and
- An evaluation of the true plant capacity indicates that it can accommodate twice the rated flow rate.

Remediation Costs

Actual costs are not available; however, the costs are competitive with other processes.

General Site Information

A full-scale, advanced oxidation process was tested at the DOE Kansas City Plant.

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Ultrafiltration

Toxic Metals in Ground Water

Technology Description

This combination chemical-ultrafiltration treatment process is intended for use on toxic metals in ground water. Ultrafiltration has thus far been applied exclusively to the removal of colloidal solids and fairly large molecules. This technology may potentially be used to separate toxic heavy metals such as cadmium, chromium, lead, mercury, selenium, silver and barium (as an in-situ formed precipitate) from ground water generated at Superfund sites. Other inorganic and organic materials present as suspended and colloidal solids may also be removed.

Ultrafiltration can be applied in combination with chemical treatment to selectively remove dissolved metal ions from dilute aqueous solutions. A high molecular weight chelating agent is added to the incoming waste solutions to form macromolecular complexes. The metal ions can then be easily removed.

Usually, each chelating polymer is marked for one metal or for a group of similar cations. Once the polymer is added, the solution is processed through an ultrafiltration membrane system that collects the macromolecular complexes (retentate) on the membrane, but allows uncomplexed ions such as sodium, potassium, calcium, chloride, sulfate, and nitrate, to pass through as filtered water (permeate). The filtered water can be recycled or discharged depending upon the metal removal requirements. A removal efficiency approaching 100 percent can be achieved for metal ions in ground water.

The retentate, which constitutes about 5 to 20 percent of the feed volume, contains the separated heavy metal ions and must be treated further. The retentate is either solidified to prevent the release of toxic metals back to the environment or recycled through the treatment process for further volume reduction.

Because many simple and non-toxic ions are allowed to pass through the membrane as permeate, they are not concentrated together with the metal ions. The retentate will have a smaller volume and the solidified product will be more resistant to leaching, due to its smaller salt content and the presence of chem-icals that retard the migration of toxic metals.

Technology Performance

Results of bench-scale tests showed the following removal rates: cadmium and mercury, up to 99 percent; lead, 90 percent; and arsenic, 10 to 35 percent. Arsenic is an anionic species, and is not as effectively removed as the other metals. Separation of non-arsenic metals was found to be more efficient in alkaline conditions. This research also indicated that ultrafiltration, unlike conventional precipitation technologies, does not require the production of large particles and, thus, may be more applicable to feed streams with high variability in metals concentration.

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Ultraviolet Radiation / Oxidation

Toxic Organic Compounds in Water

Technology Description

This ultraviolet (UV) radiation/oxidation process uses UV radiation, ozone (O_3), and hydrogen peroxide (H_2O_2) to destroy toxic organic compounds, particularly chlorinated hydrocarbons in water. Contaminated ground water, industrial wastewaters and leachates containing halogenated solvents, phenol, pentachlorophenol, pesticides, polychlorinated biphenyls (PCBs), and other organic compounds are suitable for this treatment process. The process oxidizes compounds that are toxic or refractory (resistant to biological oxidation) in concentrations of parts per million (ppm) or parts per billion (ppb).

The Ultrox system consists of a reactor module, an air compressor/ozone generator module, and a hydrogen peroxide feed system. It is skid-mounted and portable, and permits on-site treatment of a wide variety of liquid wastes, such as industrial wastewater, ground water, and leachate. The expected wastewater flow rate and the necessary hydraulic retention time to treat the contaminated water determine the reactor size. Pilot-scale studies determine the approximate UV intensity, and ozone and hydrogen peroxide doses.

Influent to the reactor is simultaneously exposed to UV radiation, ozone, and hydrogen peroxide to oxidize the organic compounds. Off-gas from the reactor passes through an ozone destruction (Decompozon) unit, which reduces ozone levels before air venting. The Decompozon unit also destroys gaseous volatile organic compounds (VOCs) stripped off in the reactor. Effluent from the reactor are tested and analyzed before disposal.

Technology Performance

The test program was designed to evaluate the performance of the Ultrox System for several combinations of five operating parameters: (1) influent pH, (2) retention time, (3) ozone dose, (4) hydrogen peroxide dose, and (5) UV radiation intensity. Contaminated ground water treated by the Ultrox system at a San Jose, California hazardous waste site met regulatory standards at the following operating conditions:

- Retention time - 40 minutes;
- Influent pH - 7.2 (unadjusted);
- O_3 dose - 110 mg/L;
- H_2O_2 dose - 13 mg/L; and
- UV lamps - all 24 operating at 64 watts each.

Out of 44 VOC samples, three were chosen to be used as indicator parameters. The VOC removal efficiencies at these conditions are presented in Table 1.

Removal efficiencies for trichloroethylene (TCE) were about 99 percent. Removal efficiencies for 1,1-DCA and 1,1,1-TCA were about 58 percent and 85 percent, respectively. Removal efficiencies for total VOCs were about 90 percent. For some compounds, removal from the water phase was due to both chemical oxidation and stripping. Stripping accounted for 12 to 75 percent of the total removal for 1,1,1-TCA and 5 to 44 percent for 1,1-DCA. Stripping was less than 10 percent for TCE and vinyl chloride, and was negligible for other VOCs present.

The Decompozon unit reduced ozone to less than 0.1 ppm (OSHA standards), with efficiencies greater than 99.99 percent. VOCs present in the air within the treatment system, at approximately 0.1 to 0.5 ppm, were not detected after passing through the Decompozon unit. Very low TOC removal was found, implying that partial oxidation of organics occurred without complete conversion to CO_2 and H_2O. The average electrical energy consumption was about 11 kW/hour of operation.

General Site Information

EPA completed a field-scale demonstration in March 1989 at a hazardous waste site in San Jose, California. EPA published the Technology Evaluation Report in January 1990 (EPA/540/A5-89/012). EPA published the Applications Analysis Report in December 1990.

Contacts

EPA Project Manager:
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U.S. EPA
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26 West Martin Luther King Drive
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Technology Developer Contact:
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TABLE 1
PERFORMANCE DATA FOR REPRODUCIBLE RUNS

	Mean Influent (µg/L)	Mean Effluent (µg/L)	Percent Removal
Run 9			
TCE	65	1.2	98
1,1-DCA	11	5.3	52
1,1,1-TCA	4.3	0.75	83
Total VOCs	170	16	91
Run 12			
TCE	52	0.55	99
1,1-DCA	11	3.8	65
1,1,1-TCA	3.3	0.43	87
Total VOCs	150	12	92
Run 13			
TCE	49	0.63	99
1,1-DCA	10	4.2	58
1,1,1-TCA	3.2	0.49	85
Total VOCs	120	20	83

Wetlands-Based Treatment

Metals in Influent Waters

Technology Description

This constructed wetlands-based treatment technology uses natural geochemical and biological processes inherent in a man-made wetland ecosystem to accumulate and remove metals from influent waters. The wetlands-based treatment process is suitable for acid mine drainage from metal or coal mining activities. These wastes typically contain high metals concentrations and are acidic in nature.

Wetlands treatment has been applied with some success to wastewater in the eastern regions of the United States. The process may have to be adjusted to account for differences in geology, terrain, trace metal composition, and climate in the metal mining regions of the western United States. The treatment system incorporates principal ecosystem components found in wetlands, including organic soils, microbial fauna, algae, and vascular plants.

Influent waters, which contain high metal concentrations and have low pH levels, flow through the aerobic and anaerobic zones of the wetland ecosystem. Metals are removed by filtration, ion exchange, adsorption, absorption, and precipitation through geochemical and microbial oxidation and reduction. In filtration, metal flocculates and metals that are adsorbed onto fine sediment particles settle in quiescent ponds, or are filtered out as the water percolates through the soil or the plant canopy. Ion exchange occurs as metals in the water come into contact with humic or other organic substances in the soil medium. Oxidation/reduction reactions that occur in the aerobic/anaerobic zones, respectively, play a major role in removing metals as hydroxides and sulfides.

Technology Performance

EPA approved second-year funding for the project under the Emerging Technologies Program. A pilot-scale system has been built to assess the effectiveness of constructed wetlands in treating the effluent from the Big Five Tunnel near Idaho Springs, Colorado. After two years of operation, the pilot study is yielding optimum results:

- pH raised from 2.9 to 6.5;
- Copper reduced to below detection limit;
- Zinc reduced by 97 percent;
- Iron reduced by 80 percent;
- Aluminum, Cadmium, and Lead decreased 90-100 percent;
- Cobalt and Nickel decreased 50 percent; and
- Biotoxicity to fathead minnows and Ceriodaphnia reduced by factors of 4 to 20.

General Site Information

EPA has selected this technology for the SITE Demonstration Program. A full-scale demonstration site has not yet been selected, but candidate sites include mineral mining facilities.

Contacts

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INNOVATIVE REMEDIAL TECHNOLOGY
INFORMATION REQUEST FORM

INSTRUCTIONS FOR SUBMITTING AN ABSTRACT

The following is the suggested format for submitting a remedial technology abstract for inclusion in the Synopses of Federal Demonstration Projects for Innovative Hazardous Waste Treatment Technologies. The format has been divided into five sections, each designed to gather specific information for the abstract. These five sections are:

- Technology Description;
- Technology Performance;
- Remediation Costs;
- General Site Information; and
- Contacts.

Although a form has been provided for your convenience, you may submit abstract information without use of this form, or you may attach additional information to this form, as necessary. If possible, this information should be presented in the same order as it appears in this example. It is understood that many abstracts will contain only partial information, as the projects are still being tested; however, please submit as much information as possible, as this will assist others in better understanding the innovative treatment technology.

Abstract information, comments, and questions relating to this project should be directed to:

Daniel M. Powell
Technology Inovation Office
U.S. Environmental Protection Agency
401 M Street, S.W., OS-110
Washington, D.C. 20460

INNOVATIVE REMEDIAL TECHNOLOGY INFORMATION REQUEST FORM

1. TECHNOLOGY DESCRIPTION

Type of Technology and Exact Technology Name (e.g., Bioremediation: Aerobic Biodegradation of Trichloroethylene):

Waste Description (e.g., PCB's in sludge):

Media Contaminated (e.g., groundwater, soil, surface water):

Targeted Contaminants and Concentrations (e.g., PCB's at 500 ppm):

Description of Treatment Process:

Description of Preliminary or Secondary Treatment, If Any:

Summary of Monitoring Results (e.g., air emissions, waste water discharge):

Limitations of Technology (e.g., weather, soil type, depth of water table):

2. TECHNOLOGY PERFORMANCE

Overall Attainment of Clean-Up Goals (e.g., residual contamination):

Summary of Data Used to Evaluate Technology Effectiveness:

Treatment Capacity (e.g., gallons per day, tons per day):

Types and Amounts of Residual Wastes (e.g., ash, steam, wastewater):

Ultimate Disposal Options (e.g., landfilling of ash):

Malfunctions and Disruptions Encountered:

Interfering Compounds:

Description and Length of Future Maintenance and Monitoring Required:

Additional Comments:

3. REMEDIATION COSTS

Total cost of Remediation Project, Not Including Site Investigations: ____________________

Cost of Remediaiton Project per Unit of Waste,
Not Including Site Investigations (e.g., dollars per ton): ____________________

Design Costs: ____________________ Time Required for Design: ____________________

Site Preparation: ____________________

Equipment Costs: ____________________

Start-up and Fixed Costs (e.g., transportation, insurance, shakedown, training): ____________________

Labor Costs (e.g., salaries and living expenses): ____________________

Consumables and Supplies (e.g., chemicals, cement): ____________________

Utilities (e.g., fuel, electricity): ____________________

Effluent Treatment and Disposal: ____________________

Residuals/waste shipping and handling: ____________________

Analytical Services: ____________________

Maintenance and Modification: ____________________

Demobilization: ____________________

Projected Costs of Future Maintenance and Monitoring per Year: ____________________

Estimated Time Required for Operation and Maintenance: ____________________

4. GENERAL SITE INFORMATION

Site Name:

____

Site Location:

____

Time Period Covered by the Project:

____

Scale of Project (i.e., treatability study, bench scale, pilot test, field demonstration or full-scale remediation):

____

Site Characterization Data (to the extent that it affects the treatment process):

____

____

____

Volume of Area Contaminated: ______________________________

Facility's Current and Previous Uses:

____

____

5. CONTACTS

Facility Contact: ____________________ ____________________ ____________________ ____________________	Remedial Action Contractor: ____________________ ____________________ ____________________ ____________________
Contractor Contact: ____________________ ____________________ ____________________ ____________________	Other Contacts: ____________________ ____________________ ____________________ ____________________

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Suggestions

If you know of additional projects that should be included in this compendium, or if you are often in need of this type of information and don't know how to find it, please make a note on this page. This is a self-addressed mailer -- just add postage, and drop it in the mail.